The Spine in Sports Injuries: Thoracic and Lumbar Spine

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Contents

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Abstract

This book chapter provides an overview of imaging in sports injuries of the thoracic and lumbar spine. Indications for imaging in trauma, overuse, as well as osteoporosis are discussed. Imaging findings in the most important diagnoses and differential diagnoses are explained in detail. Within those, overuse plays a significant role. It is important to keep in mind that congenital and developmental disorders are risk factors for overuse syndromes and degenerative diseases of the spine. Overuse trauma is most mainly seen at the lumbar spine in children or adolescents performing sports activities associated with repetitive lumbar hyperextension. Spondylosis, apophyseal damage, and scoliosis form a typical triad of overuse of the thoracic and lumbar spine. Especially, in young patients correct diagnosis not only is the basis for a successful treatment, but might also help to prevent sequelae in later days.

1 Introduction

Spinal manifestations of sports injuries or of overuse at the spine mainly result from activities in certain trend sports with high deceleration or from monotonous repetitive movement patterns. An involvement of the spine has been reported in 10–15% of sports injuries (Tall and DeVault

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1993). For many forms of sports-associated overuse, especially those located at the vertebral arches, childhood and adolescence form more than 60% of the "vulnerable phases" of life, whereas degenerative disc disease is more commonly observed in adults and has been reported to occur in only 10% in earlier decades (Micheli and Wood 1995). Among the various forms of sports injury and overuse certain relationships exist as "structures of weakness" within a kinetic chain may be prone to earlier or more severe degeneration than others.

The imaging modalities used for documenting sports injuries include conventional radiography (Box 1), computed tomography (CT, Box 2) with multiplanar reformations, and magnetic resonance imaging (MRI, Box 3). Bone scintigraphy with 99m-Tc-diphosphonates has been advocated especially for detecting stress reactions but is of limited value with respect to the continuous improvements of the spatial resolution gained with CT and MRI. Ultrasound has been described for measuring the width of spondylolytic clefts and the thickness of spinal muscles but has not been established in clinical routine (Hides et al. 1995). In the context of biomechanical concepts of trend sports the indications for imaging, the techniques of investigation, and the interpretation of normal and abnormal findings will be reviewed.

Box 1: Plain Radiography

- In many cases the primary investigation
- Enables documentation of segmental abnormalities of flexion and extension
- Evaluation of the spinal alignment
- Evaluation of fractures

Box 2: Computed Tomography

- Should be performed after severe acute traumatic events
- Enables multiplanar reformations in three planes and 3D volume reconstructions
- Shows fractures, especially tiny avulsions

Box 3: MR Imaging

- Should be performed in case of neurological deficit and can also be helpful as second-line investigation in the chronic setting
- Detection of bone marrow edemas, especially in stress reactions
- Evaluation of disc disease, spinal cord, and soft-tissue edema
- Evaluation of rupture of joint capsules/ligaments and of fractures

2 Indications

As a general recommendation based on European referral criteria and the American College of Radiology Appropriateness Criteria, CT without intravenous contrast should be used as a primary investigation in adult patients after blunt trauma of the thoracic or lumbar spine. In cases with neurological abnormalities MR imaging is thought to be the most appropriate next imaging study. Performing a CT study should usually be sufficient in patients without neurologic signs. However, due to the increasing use of the thoracolumbar injury classification and severity score (TLICS), MR imaging is requested more and more often to rule out nonstable fractures, since those normally require surgical stabilization. Patients with chronic complaints should only be evaluated radiologically if clinically indicated in most cases starting with conventional radiographs, eventually followed by MR imaging (De Jonge and Kramer 2014). An important advantage of projection radiography is its potential to document segmental abnormalities of flexion and extension. Such direct information about malalignment may also be appreciated with dedicated low-field MR units, which, however, are still infrequently available.

Specific aspects in sports medicine that should be mentioned in the referral with respect to a dedicated treatment plan include the following:

- The symptoms and signs of the biomechanical "kinetic chain" associated with the type of trauma or overuse (Kainberger et al. 2006; Lennard and Crabtree 2005).

- Red flags, i.e., signs of severe trauma that may be associated with a neurologic deficit: They should be differentiated from less severe and more commonly observed signs of pain and movement disorders due to self-limiting muscle strains.
- The urgency of “return to play,” whether the patient is a professional athlete or is involved in recreational sporting activities (Eck and Riley III 2004).

These general, as well as specific, recommendations are also true for back pain in children which is most commonly observed at the lumbar segment in conjunction with sports.

2.1 Trauma

Fractures mainly result from compression or from a hyperflexion-hyperextension movement pattern with high deceleration, acceleration, or an abrupt change of the direction of movement. With increasing frequency they are associated with trend sports with high speed or jumping movements like motor sports or kite surfing. A typical location is at the thoracolumbar junction.

After acute traumatic events, CT should be performed with multiplanar reformations in three planes. Three-dimensional volume reconstructions are helpful for documenting complex rotational malalignment but its interpretation is associated with a flat learning curve, so that specific experience is needed in using this technique (Schroder et al. 2003). MRI is especially indicated if neural structures seem to be involved which may be caused by a hematoma or by direct violation. MRI is further helpful for documenting a rupture of joints or ligaments, or a disc herniation that in the adolescent athlete may result from abrupt rotational or hyperflexion movements (Fig. 1).

Late sequelae of macro- or microtrauma are degeneration of discs or facet joints and may be documented with conventional radiographs, CT, or MRI (Fig. 2).

Fig. 1 A 17-year-old professional basketball player with lumbar disc dehydration and extrusion at L5/S1 on a sagittal TSE T2-weighted MR image. Additionally, multilevel Schmorl’s nodes

2.2 Overuse

Stress reactions of the bone most commonly manifest at the caudal lumbar spine and are associated with track-and-field athletics, dancing, and various activities associated with lumbar hyperextension. Conventional radiographs which include views in two plains and a lateral view of the lumbosacral junction should be exposed. They are generally more reliable than oblique views which, especially in case of an associated scoliosis, may be difficult to be interpreted

Fig. 2 A 21-year-old male high jumper. Sagittal T2-weighted MR image reveals a single Schmorl's node with surrounding bone marrow edema (in keeping with an "acute" Schmorl's node) at the upper endplate L5. The presence of bone marrow edema may correlate with the patient's symptoms

(Amato et al. 1984). A CT with multiplanar reconstructions may be added in equivocal cases. MRI should be performed for assessing the width of the spinal canal and for an associated degenerative disc disease. Sacral stress fractures are less commonly observed and result from excessive transmission of load from the spine to the lower extremities due to jogging, basketball, volley ball, or aerobics (White et al. 2003). MRI is the modality of choice in these cases whilst the diagnosis may be missed with conventional radiographs (Fig. 3).

Imminent spondylolysis should be suspected and radiologically detected in adolescents with unspecific activity-related lower back pain for more than 3–4 weeks (Leone and Cassar-Pullicino 2019); thereby healing can be enabled, progression can be prevented, and a return to sport is possible. This requires activity restriction, rest, and physical therapy with or without a spinal brace for 3–6 months, from the point that a stress reaction was diagnosed; otherwise non-union/olisthesis occur and surgical interventions might be necessary (Overley et al. 2018).

Overuse of the sacroiliac joints in the athlete is often associated with asymmetric load on the pelvic ring and imaging, especially MRI, should be performed to document bone marrow or soft-tissue edema as being important footprints of stress or trauma (Brolinson et al. 2003). Hypertrophy of the piriformis muscle with or without additional muscle fibers originating from the anterior sacral surface may be associated with sciatic nerve entrapment and cross-sectional imaging may have the potential to clarify its clinical appearance (McCrory and Bell 1999).

2.3 Osteoporosis

A decreased bone mineral density has been described in young gymnasts or in ballet dancers with or without secondary amenorrhea (Kaufman et al. 2002). A bone densitometry should be performed in any case of an unclear stress fracture, especially in young active women, as high-intensity training may be regarded as a significant risk factor for developing osteoporosis (Braam et al. 2003). Positive effects of sporting activities on bone density, on the other hand, have been reported for short-term high-performance activities such as sprint, tennis, fencing, as well as weight lifting or heavy athletics (Felsenberg and Gowin 1998; Sabo et al. 1996; Seidl et al. 1993).

3 Image Interpretation

The image analysis has to be focused on the distribution, characteristics, and differential diagnosis of so-called footprints of kinetic chains. The

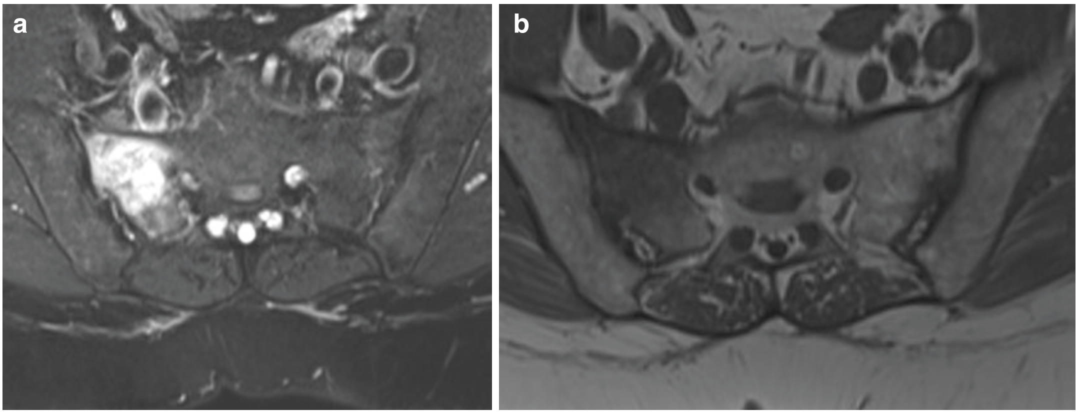

Fig. 3 27-Year-old judoka athlete with right-sided pain since 5 weeks. Unilateral, right-sided stress fracture of the massa lateralis S1. MRI with **a** para-axial STIR and **b** para-axial T1-weighted MR image shows bone marrow edema at the right hemisacrum (case courtesy of F.M. Vanhoenacker)

spinal kinetic chains associated with sports are caused by the effects of high kinetic energies in cases with acute trauma and by effects from monotonous repetitive forces (rowing), asymmetric forces (golf, cricket), or various and less standardized movement patterns (gymnastics).

3.1 Imaging Findings

3.1.1 Trauma

Osseous lesions occur, in contrast to injuries of the cervical spine, less commonly and with less severity observed at the thoracolumbar spine as it has been described in detail for pole-vaulters (Boden et al. 2001). Reports include compression fractures, mainly in contact sports, cycling, or skiing, and flexion-distraction injuries in gymnasts (Katz and Scerpella 2003). The facet lamina fractures (posterior column fractures) of the thoracic spine and the facet posterior fractures of the lumbar spine are typical fracture types that are associated with sports. The concept of the functional reserve of spinal capacity, originally developed by Burrows, may be applied on the thoracolumbar spine (Prasad et al. 2003). Rarely fractures of the superior articular process of S1 can be a source of pain in elite athletes; thus this diagnosis should be kept in mind and it should be noted that in some cases such fractures might be easier to detect on CT than on MRI (Skaggs et al. 2012; Kojima and Asamoto 2017).

Physeal injuries are referred to as the vertebral growth plate. Slipped vertebral ring apophysis may occur in childhood if the apophysis together with the adjacent disc that is tightly fixed by the annulus fibers is displaced posteriorly into the spinal canal. It is a rare entity which usually results from lifting heavy weights.

Spinal cord injury without radiographic abnormality (SCIWORA) is an entity described for children whose spinal structures are of less stiffness than in adulthood. In a meta-analysis it was shown that, in 13%, SCIWORA was associated with sports injuries and 26% occurred at the thoracic spine whereas it was virtually never observed at the lumbar spine (Launay et al. 2005). The prognosis can be improved if the syndrome is diagnosed early and adding MRI to the diagnostic workup may show neural and extraneural injuries.

Muscle strains may be detected rarely with MRI (Bennett et al. 2006).

3.1.2 Congenital and Developmental Disorders

Variants and congenital diseases occur especially at the lumbosacral junction and have, as intrinsic risk factors for overuse syndromes and degenerative diseases, to be assessed radiologically. An incomplete fusion of the vertebral arch at the level of S1 may be associated with a spondylolysis of L5. From the three patterns of incomplete fusion (type I with a wide cleft, type II with small contact between the divided branches, and type

III with overlapping borders), types II and III are regarded as parts of retarded spinal development and are typically observed together with a spondylolysis of L5 (Fig. 4) (Niethard et al. 1997).

In the radiological assessment of scoliosis with respect to sports the Cobb angle should be measured to differentiate more severe forms (higher than 20°) in which axial load should be prohibited from less severe forms (Hochmuth et al. 2002).

3.1.3 Stress Reactions of the Bone and the Discovertebral Junction

Spondylolysis and apophyseal damage form, together with scoliosis, a characteristic triad of overuse of the thoracic and the lumbar spine. Accelerated growth (growth spurt) during adolescence is regarded as an important trigger mechanism in its development (Seitsalo et al. 1991).

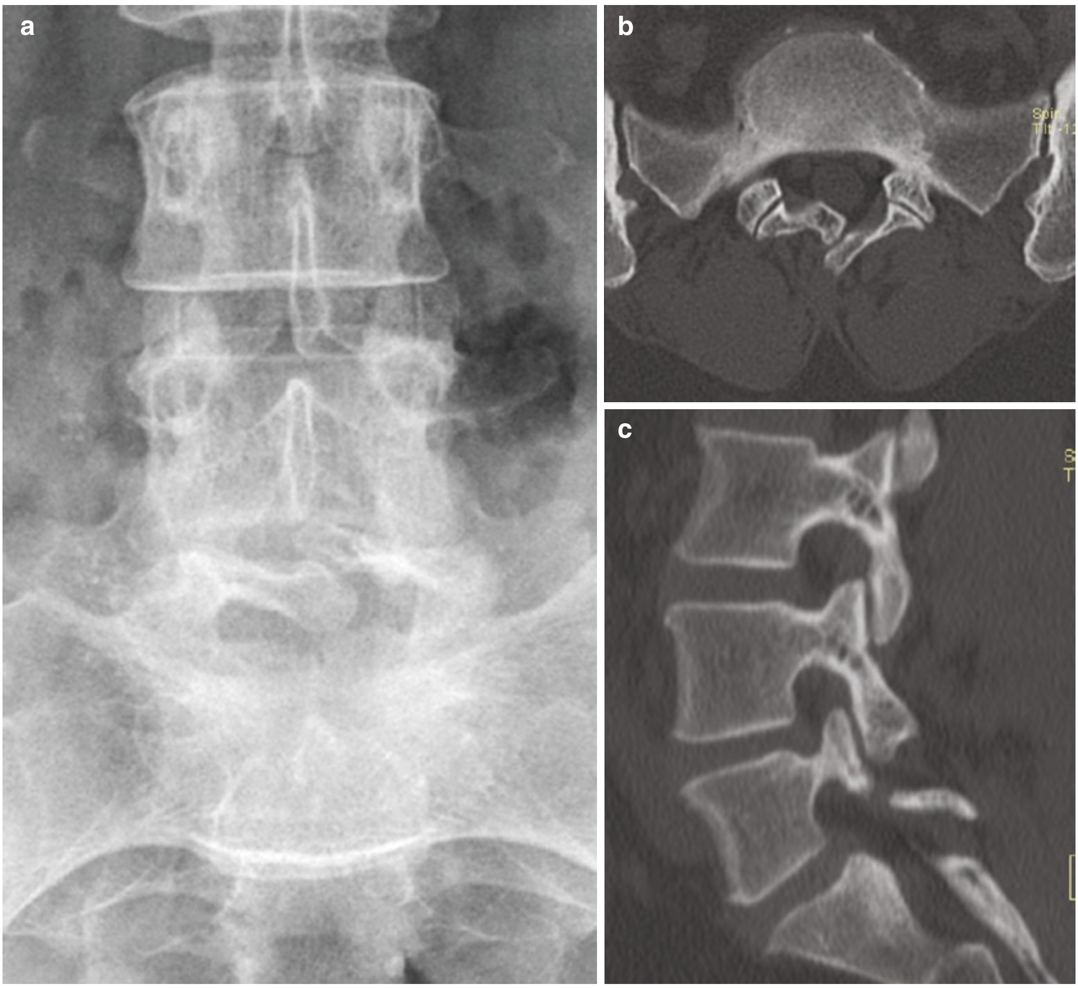

Fig. 4 Former gymnast with incomplete fusion of the vertebral arch of S1 on **a** plain radiograph (type III) and **b** axial CT image and **c** interruption of pars interarticularis of L5 on CT (case courtesy of F.M. Vanhoenacker). **d** Sagittal T2-weighted MR image in another 29-year-old athlete with spondylolysis and anterolisthesis L5 as well as disc bulging L5/S1 and consecutive stenosis of the neuroforamen. **e** Axial CT scan in another gymnast with unilateral left spondylolysis shows an “incomplete ring sign” at the left side and contralateral sclerosis of the right pedicle (case courtesy of F.M. Vanhoenacker)

Fig. 4 (continued)

3.1.4 Osseous Stress Reactions

Spondylolysis manifests typically at the age of 6 years and is in more than 90% located at the fifth lumbar vertebra (Fig. 4), and less commonly at the fourth or at other segments. Sometimes, two or more segments of the lumbar spine may be involved. A reduced resistance of the interarticular portion of the vertebral arch and increased stress due to hyperlordosis are regarded as main causative factors. Therefore, spondylolysis is defined as a stress fracture and many concepts about its etiology and its treatment are based on this definition (Standaert and Herring 2000). According to Vialle et al. (2005), radiologic signs support the concept that a global dystrophic pattern of the lumbosacral junction is an underlying cause of severe spondylolisthesis with increased shear stresses. Spondylolysis seems to be, although asymptomatic forms have been observed in rare cases, the most common cause of back pain in athletes and occurs with higher frequency than in the general population in which it occurs in about 10% (Rossi and Dragoni 1990; Soler and Calderon 2000). There is a racial preponderance with a prevalence of 5–7% in Europeans, 9% in Bantus, 7–10% in Japanese, and up to 50% in Eskimos (Engelhardt et al. 1997). Typical movement patterns for the development of spondylolysis have been described (Table 1) (Bono 2004).

In tennis players, the pars interarticularis is a common site of stress injury with sudden hyperextension of the spine secondary to the serving

Table 1 Common forms of applied forces leading to spondylolysis (modified from Junghanns 1986)

Applied force	Type of activity
Repetitive hyperextension maneuvers	Gymnastics, wrestling, diving, throwing sports, basketball, volleyball, pole vaulting, certain swimming styles (butterfly), high diving
Strong muscle forces	Body building, wrestling, hockey
Repeated monotonous exercises	Rowing
Rotational motion creating unilateral defects	Throwing sports, golf
High and various degrees of movement	Football, track-and-field athletics, dancing, figure skating

and ground stroke motions, increased repetitive motion due to double-handed ground strokes, and increased use of the top spin on hard courts being some of the many potential etiological factors (Rajeswaran et al. 2014).

Spondylolysis results from a low stress resistance of the pars interarticularis of the vertebral arch on one side, and from high stress applied to this structure on the other side. Low stress resistance is mainly due to an elongation and thinning of the pars and is exaggerated by a prominent lordosis of the lumbar spine. Such lordosis especially develops at between 6 and 8 years and is associated with a physiological flexion of the hip joints. Radiological evidence of a lumbosacral transitional vertebra, a congenital cleft of the posterior arch of the S1 segment (spina bifida occulta), or a facet joint anomaly is strongly associated with spondylolysis of L5 (Standaert and Herring 2000). A spina bifida occulta has been described to occur between 13% and 58% concomitant with spondylolysis (Niethard et al. 1997). Spondylolysis also occurs in patients with Marfan syndrome and Ehlers-Danlos syndrome; in the latter disorder it may be severe. Osteogenesis imperfecta and osteopetrosis are other forms of systemic diseases related to spondylolysis. Repeated microfractures are mainly related to hyperextension movements, thus amplifying the lordotic state. Muscle strength and tension may influence the development of spondylolysis by shortening or tightness of the hamstring muscles of the thigh with increased tension on the posterior vertebral arches of the lower lumbar spine. Weakening of the spinal and the anterior abdominal wall muscles is a precursor in the development of spondylolysis, too, whereas strengthening parts of these muscles should have a preventive effect.

In the later course of spondylolysis, fibrous or bony callus formation at the pars defect site may develop. Bony outgrowths, facet joint arthrosis, or instability may lead to nerve root impingement with leg pain, numbness, or weakness.

A cleft of the vertebral arch detected on oblique views ("Scotty dog" or "LaChapel's dog") is a direct sign of spondylolysis. More sensitive imaging techniques for the diagnosis may be a lateral view of the lumbosacral junction, multiplanar CT, and MRI. Flexion and extension views are helpful to document signs of hypermobility. These findings and a cleft of more than 3 mm width are indicators of a late phase of spondylolysis with a poorer prognosis than during the early phase (Engelhardt et al. 1997). During anteflexion, a complex gliding mechanism may be observed fluoroscopically: the vertebra, partially fixed at the facet joints, moves with a sudden jump in a retrolisthetic position. With such abnormal movements the increased stress on the facet joints and the spinal nerves in the adjacent intervertebral foramina may be explained. On axial CT or MR images, the spondylolytic clefts adjacent to the facet joint spaces may appear as the "double facet joint" or "incomplete ring" sign (Fig. 4). In the case of unilateral spondylolysis, reactive sclerosis may develop at the contralateral pedicle (Fig. 4). On MR images, bone marrow edema within the vertebral arch or a bony sclerosis may be observed in 40% and MR imaging may be used as a reliable modality for the diagnosis of juvenile spondylolysis (Campbell et al. 2005; Ulmer et al. 1997). Stäbler et al. (2000) have described the importance of detecting stress reactions (T1-weighted hypointense and T2-weighted hyperintense; bone marrow edema) without visible fracture lines for early diagnosis.

The degree of destruction of the interarticular portion may be graded as follows: 0, normal; I, intact with bone marrow edema (stress reaction); II, sclerosis or low signal with intact cortex; III, indeterminate; IVa, cortical discontinuity on one side of pars; iVb, complete discontinuity of pars (Campbell et al. 2005). Sherif and Mahfouz (2004) mentioned the interposition of fatty tissue between the dural sac and the spinous process of L5 as a helpful indirect sign of spondylolysis.

An isthmic spondylolisthesis may develop in 4% of spondylolysis (Fig. 4) (Danielson et al. 1991). It is a forward movement of the body of one of the lumbar vertebrae on the vertebra below it, whereas the posterior joints and the neural arches are aligned with the posterior elements of the inferior vertebral body. Spondyloptosis is a fully dislocated vertebral body. Spondylolisthesis occurs in preadolescents and is found in up to 50% of athletes with persistent back pain. Symptoms may not occur until later in life. In a longitudinal study by Fredrickson et al. (1984), three-quarters of all individuals with spondylolysis had an identifiable pars defect on plain films by age 6, and approximately 75% of these patients had evidence of a slip at that time. Further progression of the slip in adulthood is rare (Floman 2000).

An early gliding of more than 20% is the only predictor for spondylolisthesis that has been described (Seitsalo et al. 1991). Muschik et al. (1996) observed a progression of this entity especially during growth spurt. Meyerding grading into four stages oriented on the sagittal diameter of the subjacent vertebra has been generally accepted (Meyerding 1932). On axial CT or MR images, an oval elongation of the spinal canal and a stenosis of the intervertebral foramina with atrophied perineural fat are associated findings.

Other forms of spinal stress fractures are rare and may be observed at the cervical spine. At the chest, such fractures generally occur at the ribs rather than at the thoracic spine (Karlson 2004). The ribs of the lower chest may be injured in golfers or rowers, whereas fractures of the first rib may occur in weight lifters, throwers, or rucksack-carrying hikers.

3.1.5 Discovertebral Overuse

Apophyseal damage or microfractures of the vertebral endplates are typical findings in weight lifters, wrestlers, and track-and-field athletes and are part of Scheuermann's disease. It is also observed in professional downhill skiers (Ogon et al. 2001). There is a clear genetic predisposition for developing Scheuermann's disease, but observations in adolescents with high athletic activity underline the aspect of overuse in its etiology especially in the "atypical" or "traumatic" subtype which is located at the thoracolumbar junction (Alexander 1977).

With respect to the different types of endplate reactions that may or may not be associated with Scheuermann's disease, there is general agreement that Schmorl's nodes, especially their chronic forms, are not indicators of athletic injury, whereas anterior lesions are related to sports and may be associated with back pain (Ogon et al. 2001).

These anterior lesions (Fig. 5), the limbus vertebrae (LV) or slipped vertebral apophysis, are a disorder with cartilaginous node formation due to intraosseous disc penetration at the border of the rim apophysis. During flexion, the anterior part of the disc is pressed under the superior nonfused endplate. It typically occurs during the second decade of life after the rim apophysis has formed (7–9 years) and before its fusion with the vertebral body. The abnormality is typically observed in athletic adolescents (Ross et al. 2004).

The degree of thoracic kyphosis is increased in adolescent gymnasts but, in contrast to heavy workers, does not reach the pathologic ranges that are associated with Scheuermann's disease (Hochmuth et al. 2002).

3.1.6 Degenerative Joint and Disc Disease

Degeneration, despite its higher frequency in the later decades of life, may be observed in young athletes—especially gymnasts and wrestlers—and occurs rather in the nucleus than in the annulus (Sward 1992). It has also been described that disc herniations occur slightly more often in elite tennis players than in asymptomatic nonathletes

Fig. 5 Limbus vertebrae in two different patients. **a** Sagittal TSE T2-weighted MR image shows a sequela of an intravertebral herniation separating the anterosuperior ring apophysis L4 in a 33-year-old swimmer and biker. Note also disc degeneration at L3/L4. **b** Conventional radiograph and **c** CT scan in another gymnast showing separation of the rim apophyses at multiple levels (cases courtesy of F.M. Vanhoenacker)

(Rajeswaran et al. 2014), which can be explained by the repeatedly high degree of axial loading and axial rotation during the serving and ground stroke motions; the majority of these disc herniations were at the levels L5/S1 and L4/L5. In the same way as with Scheuermann's disease, a genetic influence has been proposed for the development of disc degeneration in children. Abnormal segmental movement patterns in the forms of hyper- or hypomobility or of instability may be best documented on flexion and extension views.

Facet joint arthropathy has been described as the most common abnormality in almost 90% of asymptomatic elite junior tennis players; it is thought to be the result of repeatedly axial rotation and impaction of the facet joints, which occurs during the tennis serve, and ground top spin strokes. Synovial cyst formation arising from the facet joints has also been described to be relatively prevalent in young elite tennis players; however, most of those synovial cyst formations occurred posteriorly (Rajeswaran et al. 2014).

3.2 Differential Diagnosis

Back pain in athletes not resulting from sporting activities may be due to diseases commonly occurring in adolescents and young adults, especially rheumatic diseases, tumors, or unexpected trauma. Their first clinical manifestation may, however, be in conjunction with sporting activities and characteristic imaging findings can be a hallmark of the correct diagnosis.

Inflammatory back pain is a typical symptom of seronegative spondylarthropathies (ankylosing spondylitis, psoriatic arthropathy, and reactive arthritis). Bone marrow edema, sclerosis, or erosions may be observed at the sacroiliac joints or in the form of anterior spondylitis at the thoracolumbar junction; endplate changes, like the Andersson lesions, are well-known manifestations of ankylosing spondylitis. However, also bone marrow as well as soft-tissue edema of the facet and the costovertebral joints are typically seen in patients with seronegative spondylarthropathies.

Osteoid osteoma is typically located at the pedicle roots of the lumbar spine with a characteristic calcified nidus within an osteolysis. CT is the modality of choice for its detection, whereas MRI may be difficult to be interpreted because of the various tissue contrast of the nidus. However, osteoid osteoma should always be considered in case of marked bone marrow and adjacent soft-tissue edema in the typical location in a patient without trauma between 10 and 35 years; to identify a nidus, CT is recommended. Bone scintigraphy is helpful especially if performed with single-photon emission computed tomography (SPECT). Primary malignant bone tumors (osteosarcoma, chondrosarcoma, chondroma) or malignant bone marrow diseases are generally rare and present with osteolysis and typical calcification patterns.

Non-accidental trauma (battered child syndrome) has to be considered in any case of unclear trauma, especially if manifestations do not match with patterns of kinetic chains of if they are observed asynchronically. Apophyseal injuries at the thoracic or lumbar spine have been described to be associated with this entity (Levin et al. 2003).

Congenital vertebral clefts at the lumbar spine are in most cases observed as median interruptions of the vertebral arch, and less commonly as paraspinal, retroisthmic, or retrosomatic forms. They have to be differentiated from spondylolysis vera.

4 Conclusion

The biomechanics of all major types of sports with spinal involvement along with the typical movement patterns is the basis for the diagnosis and treatment of pain, restricted motion, or other associated findings (Lennard and Crabtree 2005). Cross-sectional imaging modalities and attempts to document the spinal kinematics are promising techniques to document normal as well as abnormal states and movement patterns. Imaging interpretation should therefore be based on "footprint" patterns of kinetic chains associated with certain athletic activities.

Things to Remember

- The spine is involved in 10–15% of sports injuries.
- Overuse trauma of the vertebral arches is mainly seen in childhood and adolescence,

whereas degenerative disc disease is most commonly seen in older athletes.

- Overuse trauma is most commonly seen at the lumbar spine in sports activities associated with lumbar hyperextension. Spondylosis, apophyseal damage, and scoliosis form a typical triad of overuse of the thoracic and lumbar spine.
- Congenital and developmental disorders are risk factors for overuse syndromes and degenerative diseases of the spine.
- A limbus vertebra occurs typically in athletic adolescents.

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