

LOW BACK PAIN IN THE YOUNG TENNIS PLAYER

THE RISK OF SPONDYLOLYSIS

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INTRODUCTION

Modern tennis movements require frequent, repetitive and rapid rotation of the lumbar spine which predisposes players to acute and chronic injuries. Low back pain (LBP) in the young active athlete may not be as abnormal as once suspected. More than 50% of children experience some back pain by 15 years of age¹. Some reports have shown that 50 to 85% of immature patients with back pain will have underlying pathology².

LBP is a common injury among tennis players. In a prospective study of junior tennis players, LBP was one of the most common complaints and the most recurrent injury³. Significant differences exist between the aetiology of LBP in the young athlete and LBP in the adult. A definable cause of the LBP can be determined in approximately 62% of young athletes^{4,5}. Spondylolysis accounts for 47% of LBP in the adolescent athlete, followed by discogenic

pain and muscle-tendon strain. In adult patients, discogenic pain accounts for 48% of back pain, musculo-tendon strain for 27%, spinal stenosis or osteoarthritis for 10% and spondylolysis for 5%⁶.

Spondylolysis refers to a defect in the pars interarticularis of a vertebra⁷. The pars interarticularis is the narrow part of bone between the superior and inferior articular processes. It represents the junction of the pedicle, the articular facets and the lamina (Figure 1).

Spondylolysis constitutes a spectrum of diseases ranging from bone stress to a bone defect and spondylolisthesis. Repetitive bone stress causes bone remodelling and may result in spondylolysis, a non-displaced fracture of the pars interarticularis, which may become unstable leading to spondylolisthesis⁸. Spondylolisthesis refers to the slipping of one vertebra relative to an adjacent vertebra⁷. Dysplastic and isthmic

are the two subtypes of spondylolisthesis found in children, with the latter accounting for approximately 85% of cases. The severity of spondylolisthesis is graded according to the percentage of translation of the cranial vertebra relative to the caudal vertebra:

- grade I < 25%
- grade II 26-50%
- grade III 51 to 75%
- grade IV 76 to 100%
- grade V >100% (spondyloptosis).

The majority (75%) of the cases of spondylolisthesis are grade I and 20% are grade II. A simpler classification system divides spondylolisthesis into 'stable cases' (translation <50%) and 'unstable cases' (translation >50%).

Spondylolysis has an incidence of 4.4 to 6% in the general population but it is much more prevalent in athletes^{7,8}. Athletes who participate in hyperextension sports have an increased risk for spondylolysis: divers

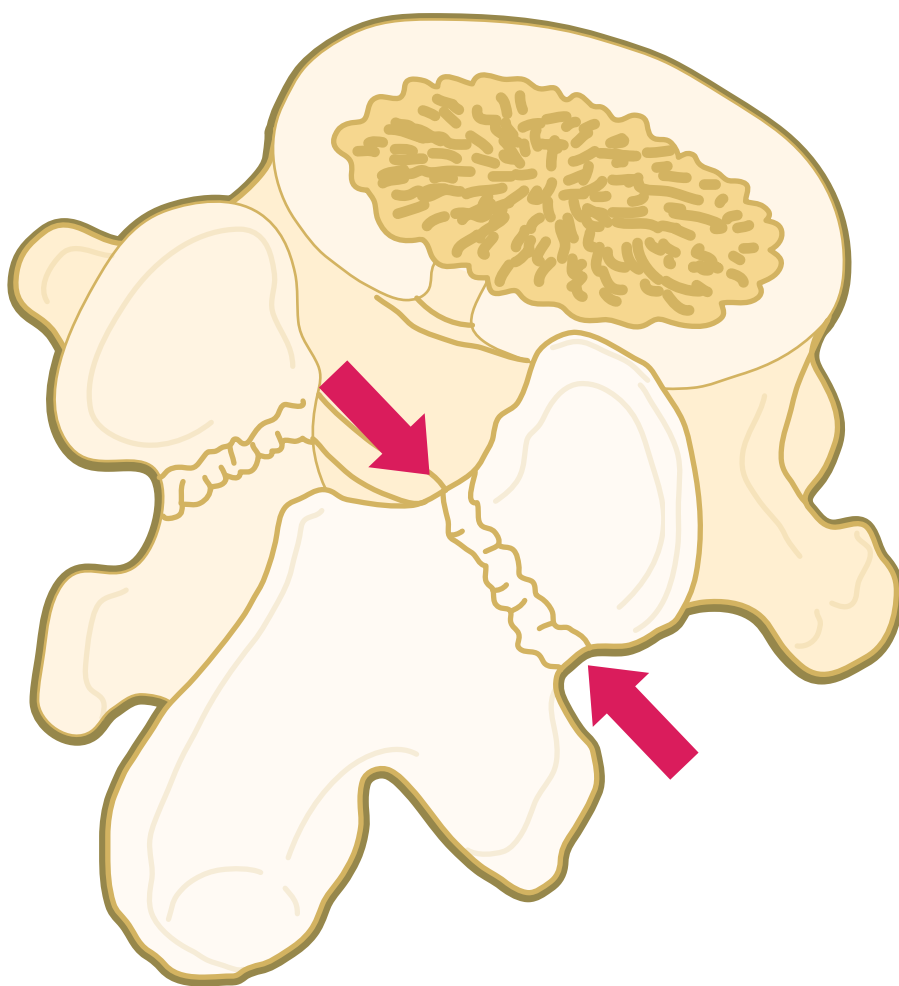


Figure 1: Bilateral injury of the pars interarticularis.

(43%), wrestlers (30%), throwing athletes (27%), weight lifters (23%), gymnasts (17%) and rowers (17%)³.

Modern tennis requires frequent repetitive and rapid rotation of the lumbar spine during groundstrokes and marked lumbar hyperextension during serving. Alyas et al⁹ found a high rate of injuries in the posterior aspect of the lumbar spine in asymptomatic young players with 27.3% showing pars injuries in MRI examination. Maquirriain et al¹⁰ reported pars lesions as the second most common type of stress injuries in elite tennis players, particularly affecting those under 18 years of age.

This review article will provide an update on the clinical aspects of spondylolysis in the competitive young tennis athlete, will discuss the relevance of different imaging modalities in the management of the athlete with spondylolysis and aim to analyse tennis biomechanics and weight-training

exercises related to the development and rehabilitation of spondylolysis.

PATHOPHYSIOLOGY AND BIOMECHANICS

Three-dimensional finite element studies of the normal lumbar spine have shown that the pars interarticularis is the weakest structure in any type of lumbar motion and L5 is the vertebra subjected to the greatest amount of static and dynamic stress¹¹. Higher stresses were found during extension and rotation at the ventral aspect in all loading modes^{12,13}. Finite element studies also showed high loads on the pedicle, so a pedicle stress fracture may be associated with contralateral pars lysis.

The pathophysiology of spondylolysis is still controversial, with two main mechanisms involved. When the lumbar spine extends, the inferior articular process of the cranial vertebra impacts the pars interarticularis of the caudal vertebra.

Repetitive impacts can produce a stress or fatigue fracture of the pars interarticularis. Lumbar hyperextension sports activities and lumbar hyperextension secondary to spinal deformities, such as Scheuermann's disease are associated with spondylolysis¹⁴.

Direct compression by means of a 'nutcracker' mechanism is one explanation, but another is that the pars interarticularis fails in tension through a traction mechanism. Which of the two mechanisms are more likely to be present in a given individual is thought to be determined by the lordosis of the spine and the lumbosacral relationship⁷. Given the difficulty in healing of stress fractures due to tensional overload and the frequently insidious onset of back pain, the tension mechanism may be the most common in young tennis players with spondylolysis.

A thorough understanding of spinal growth anatomy and physiology is important when treating young patients with LBP, since most back problems of children and adolescents are related to this. Since the extremities undergo an earlier growth spurt and also stop growing earlier than the spine and thorax, the body proportions change continuously as do body weight, muscle force and muscle length. Therefore, there is a continuous change of the individual biomechanics, particularly during the pubertal growth spurt. Strenuous physical activity may cause structural abnormalities: the incidence of LBP, MRI abnormalities and larger angles of thoracic kyphosis and lumbar lordosis are associated with greater cumulative training time and certain sports.

CLINICAL PRESENTATION

The incidence and prevalence of LBP in young patients has continued to increase, with the rate in adolescents nearly equivalent to that found in adults. Back pain is more prevalent in teenagers than in younger children and females have LBP more often than males. When evaluating a young athlete with LBP, consideration must be given to the many differential diagnoses that can produce similar symptoms. Disorders are often chronic by the time the patient presents for professional care. Although a lot of LBP in these young patients is muscular in origin, there are several findings that

should trigger increased concern, such as night pain, marked hamstring tightness, pain with lumbar hyperextension or any neurologic finding. Adolescents have a higher incidence of non-muscular causes of pain, including tumours⁵. Therefore, it is important to attempt to identify a particular cause of a patient's back pain. The



Figure 2: Oblique X-ray views of the lumbar spine showing the 'Scotty dog' figure, the ear of which is the superior articular process, the eye is the pedicle, the nose is the transverse process, the neck is the pars interarticularis and the front limb is the inferior articular process. Spondylolysis is seen as a broken neck or a collar on the 'Scotty dog' (arrow).

most common identifiable cause of LBP in an adolescent is spondylolysis and overall posterior elements injuries of the spine may account for up to 3 out of 4 cases¹⁵.

However, there are many differential diagnoses, both spinal and non-spinal, for LBP in athletes. Although spinal diseases are on the top of the orthopaedic surgeon's list, it is important to consider the non-orthopaedic diagnoses, including intrapelvic conditions (e.g. ovarian cysts), renal and urinary tract diseases. Although uncommon, different tumours can cause back pain in children. The most common spine tumours in children are osteoid osteoma and osteoblastomas.

Several risk factors for lumbar injury and back pain are often present in young competitive tennis players:

- prior back injury,
- decreased range of motion,
- poor conditioning,
- excessive or repetitive loading,
- improper play technique and
- abrupt increases in training.

A history of prior LBP was found to be the most significant predictor of further lumbar injury¹⁶. Family history, gender and race all are implicated in spondylolysis. It occurs in 15 to 70% of first-degree relatives of individuals with the disorder. Lysis is 2 to 3× more frequent in boys than in girls, but slippage affects girls 2 to 3× more often than boys. The prevalence of spondylolysis is approximately 6% in the white population, 2 to 3× higher than in black people⁷.

Progression to a spondylolisthesis is usually seen during the growth spurt, with minimal change after the age of 16. Progression to a slip does not cause pain and sports activity does not predispose to further displacement⁶. Patients with higher grades of spondylolisthesis and higher slip angles, a measure of lumbosacral kyphosis, have a higher risk of progression.

The child may display lumbar hyperlordosis, which may be the cause of spondylolysis or lumbar flattening if he or she has severe pain or a high grade spondylolisthesis. Palpation may cause discomfort in the paravertebral areas, usually around L5. Hyperextension of the lumbar spine may cause pain, particularly during ipsilateral single-limb stance ('stork test')⁵. While this test is not specific for pars stress injury, it is highly suggestive of some type of derangement of the posterior elements of the spine. Hamstring contracture is common, although the mechanism of this is unknown. A child may have a radiculopathy that manifests as changes in sensation, a motor deficit or tension signs distinct from the hamstring contracture. Scoliosis may be associated with spondylolysis. When scoliosis is due to pain, it usually resolves spontaneously following successful treatment of the lysis.

History and physical examination findings are suggestive but not diagnostic of spondylolysis. If the pain is prolonged or severe enough an aggressive imaging work-up for diagnosis should be initiated.

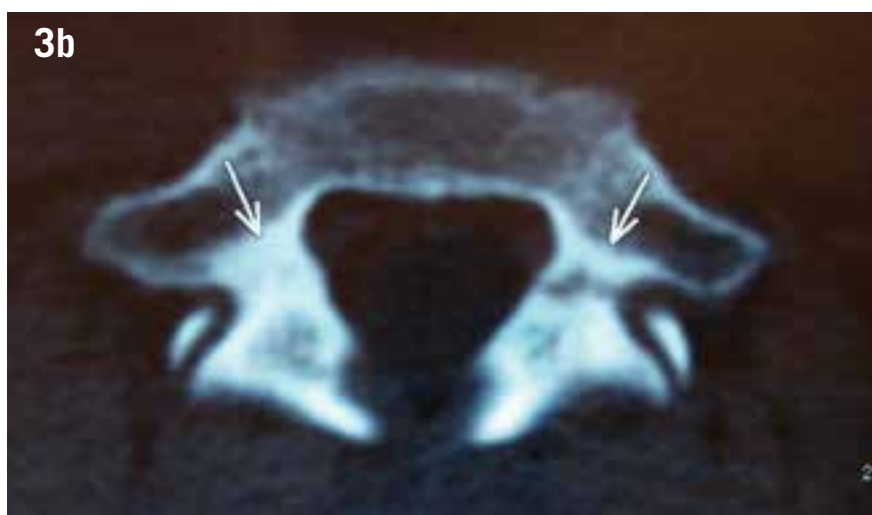


Figure 3: (a) Lateral CT view of a lumbar 5 vertebra showing a defect in the ventral side of the left pars interarticularis, (b) Axial view of the same lesion.

IMAGING

Imaging studies are the key to identify significant causes of LBP in young athletes. If a spondylolysis is suspected, early use of diagnostic studies is essential.

Plain radiographs of the lumbosacral spine should be obtained first. Historically, this consists of an X-ray series including anteroposterior, lateral and oblique views. The anteroposterior view may detect an unrecognised scoliosis, but more importantly, it can identify *spina bifida occulta*. A lateral view helps to identify spondylolisthesis or lytic lesions in patients who have spondylolysis. Bilateral oblique positioning allows for easier visualisation of the pars interarticularis. Unfortunately, the presence of a pars lesion on plain radiographs is not diagnostic of an active lesion. In fact, many asymptomatic people have pars defects on screening radiographs. For this reason, many practitioners obtain only anteroposterior and lateral radiographs in their initial work-up, knowing that additional tests to determine the metabolic activity of the bony spine will be needed to confirm the diagnosis. Oblique lumbar X-ray views are useful to depict a pars defect (Figure 2). Some authors reported that there is no difference in sensitivity and specificity between four and two-view studies in the diagnosis of spondylolysis in adolescents.

Full-length radiographs of the spine are essential to determine spinal balance, especially in the sagittal plane and to evaluate associated deformity. Flexion and extension lateral radiographs help to determine how much postural reduction of the lumbosacral angulation and translation may be obtained. For coronally oriented pars fractures, the lateral view of a plain radiograph is more suitable rather than the oblique view for diagnosis. The degree of the slip, slip angle, sacral inclination, chronicity of the slip and pelvic incidence may all be seen on the lateral radiograph. The 'sacral inclination' is the angle between the posterior and vertical aspects of the sacrum and a value of $>60^\circ$ is associated with progression.

Radiographs are usually insufficient for the diagnosis of spondylolysis, advanced imaging studies including bone scans, CT and MRI can be used. In many instances, the next step is to obtain a nuclear medicine scan because it is the best imaging modality to localise an area of abnormal

bone activity. It is useful in identifying tumours and spondylolysis. Bone scans, though not very specific, are highly sensitive for detecting increased bony metabolism and may be the most sensitive tool for diagnosing pars lesions. If a bone scan is obtained to evaluate or diagnose spondylolysis, a single photon emission tomography (SPECT) should be obtained at the same time because it provides 10 to 20× more contrast than planar bone scintigraphy, increases the sensitivity and improves anatomic localisation of skeletal lesions without exposing the patient to additional radiation⁸ (Figure 3). In addition to facilitating diagnosis, bone scans may aid in the treatment of spondylolysis. Increased signal intensity suggests osseous activity and healing potential, whereas absence of an increased signal suggests a non-union and diminished healing potential.

If SPECT demonstrates a pars lesion, a thin-cut computed tomography (CT) through the area of abnormality on SPECT is recommended to confirm the diagnosis and the stage of the lesion⁸. If SPECT is negative, pars stress is unlikely to be the cause of the low back pain and MRI may be helpful in identifying other causes of back pain.

CT is excellent for demonstrating and defining spinal bone lesions although young patients are exposed to a considerable amount of radiation with this type of study. CT scans may play several roles (Figure 4).

When the pars interarticularis appears normal on a CT scan but there is increased activity on the SPECT scan, a stress response or 'pre-lysis' defect is the diagnosis. On the other hand, when the pars interarticularis is seen to have a defect on a CT scan and there is no increased activity on the SPECT scan, the patient probably has a non-union with little healing potential. CT scans are also excellent for the follow-up evaluation of healing to rule out another lesion (e.g. osteoid osteoma), when there is an atypical presentation and for surgical planning in cases of dysplastic vertebrae or associated anomalies. CT is also helpful to depict ossicles of lumbar articular facets, which may represent part of a spectrum of stress-induced changes in the posterior neural arch.

The role of MRI in the imaging work-up of athletes with suspected spondylolysis is still controversial. Some studies reported that MRI missed a pars injury in 50% of adolescents¹⁸. In patients with a history or physical findings suggestive of spondylolysis, such as localised pain of the lumbar spine with back extension, further radiographic evaluation should be considered, even if an MRI is negative. Conversely, other authors stated that MRI appears to be useful in the early diagnosis of active spondylolysis¹⁹. MRI is useful to evaluate atypical presentations, including pre-lysis, when CT scans are normal. MRI is indicated for patients with a high grade spondylolisthesis and for those with

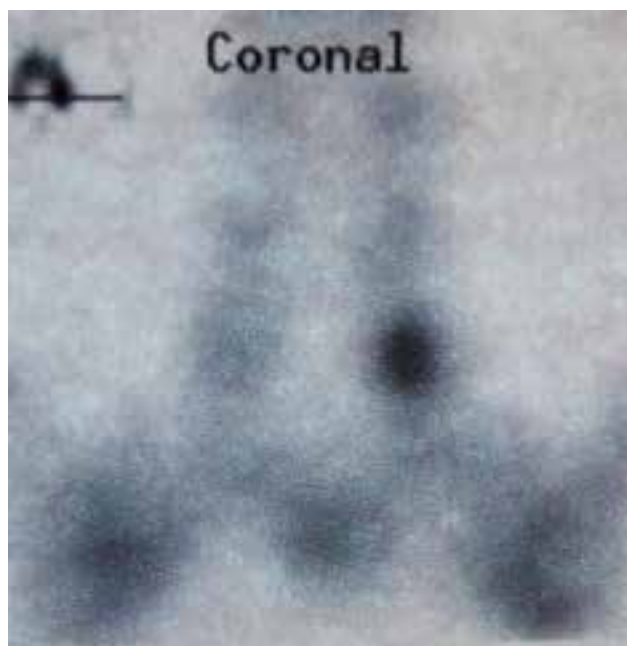


Figure 4: SPECT of the lumbar spine in a 15-year-old tennis player suffering low back pain shows abnormal radiotracer uptake in the left L5 pars interarticularis. SPECT= single photon emission tomography.

radiculopathy⁷. High signal changes on T2-MRI in the pedicle adjacent to the pars interarticularis could be an indicator of early spondylolysis. Furthermore, MRI at the 3rd month during follow-up can indicate whether conservative treatment is having success or not.

Other diagnostic tests are rarely necessary in otherwise healthy tennis players with lumbar spondylolysis. Given the high prevalence worldwide of vitamin D deficiency among children, including athletes, we recommend to determine serum 25-Hydroxy vitamin D values in all patients with a stress fracture. The bone mineral density is generally within normal values in athletes with bone stress injuries, so routine testing is not recommended.

TENNIS AND SPONDYLOLYSIS

Tennis is an acyclic and one-sided sport. Fast movements of the trunk in flexion and extension in the sagittal and frontal planes and rotational movements around the long axis are very common in tennis. The spine is a pivotal component of the kinematic chain which functions as a transfer link between

the lower and upper limbs, a force generator capable of accelerating the arm and a force attenuator during the deceleration phase of the throwing motion²⁰.

Competitive adolescent tennis players spend several years training to reach professional status. Repetitive, strenuous and intense training during the developmental stage play an important role in the adaptation of spinal morphology and the occurrence of trunk injuries.

The more painful activities identified by adolescent tennis players suffering from lumbar spondylolysis are the serve, the backhand and weight-training exercises (unpublished data). The biomechanical analysis of those specific movements perfectly matches the currently accepted pathophysiology of pars injuries.

The serve is considered as the stroke imparting the greatest stress on the lower back^{2,11,21}. The lumbar spine hyperextends and rotates with the hitting arm away from the net during the toss. The trunk then powerfully laterally flexes and the shoulders and trunk rotate toward the net as forward trunk flexion occurs (Figure 5).

Players execute various types of serves but most commonly employ the 'flat' serve and 'kick' serve as their first and second deliveries respectively. In the kick serve the racquet is positioned more posterior and more medial compared with the flat type, which could suggest an increased risk of shoulder and back injury associated with the kick serve²². The lumbar region undergoes substantial loading during both the 'kick' and the 'flat' tennis serves, with lateral flexion forces approximately 8× greater than those experienced during running. Given that these left lateral flexion forces are significantly greater in players with a history of disabling low back pain and occur simultaneously with peak vertical force, extension and right lateral rotation, this may be an important mechanism for low back pain in this population.

Young tennis players may also have referred pain during two-handed backhand hitting. Trunk rotation is greater during the forward swing with the two-handed backhand than with the one-handed backhand technique, because the non-dominant shoulder must rotate more



Figure 5: (a) Serve stroke of a young tennis player during the acceleration phase showing increase lateral bending to the non-dominant side ('pull-through mechanism'), (b) Cocking phase of the serve in a professional player with increased lumbar hyperextension for a 'kick serve'.



The more painful activities identified by adolescent tennis players suffering from lumbar spondylolysis are the serve, the backhand and weight-training exercises



completely with the follow-through. The two-handed backhand places the lumbar spine at an increased biomechanical risk, especially when reaching for a wide ball because forced rotation is applied against a relatively fixed pelvic pivot point²¹. During a one-handed backhand stroke the shoulder and elbow joints share the rotational motion necessary for the strokes and consequently reduce the maximal moments imposed on the spinal joints.

The third painful activity referred to by tennis players with spondylolysis is weight-training. Explosive type exercise including Olympic lifts (squats, dead lifts, power clean etc) and its variations, plyometric training and traditional weight-training performed with very fast cadence, are very popular among tennis players. It is often claimed that such exercises translate better into enhanced sporting performance compared to weight-training at a slow cadence, but there is considerable evidence that explosive exercises pose considerable injury risk. There is a strong association of spondylolysis with weight-training²³. Olympic lifts cause repetitive forced hyperextension of the lumbar spine, increase shear forces and can lead to spondylolysis²⁴. There is a significant increase of 'sacral slope' (resulting in horizontalisation of the sacrum) during squats which alter the

sagittal alignment of the lumbar spine and pelvis¹⁷. These changes are expected to increase the lumbar extension forces on the posterior elements of the lumbar spine and thus increase the risk of pars fractures. Strength training of adolescent athletes is still controversial. However, when young athletes are already participating in activity potentially injurious for the lumbar spine such as competitive tennis, to add another dangerous activity to their training schedule hardly seems justified.

TREATMENT

The primary goal of treatment of athletes with spondylolysis is bone healing and prevention of progression to non-union of the pars interarticularis.

Treatment of spondylolysis should be individualised and start with conservative measures. Activity modification remains the mainstay of conservative treatment of pars interarticularis lesions in the tennis player. They should be advised to refrain from participation in physical activities for the initial 4 to 6 weeks following the diagnosis of spondylolysis, after which time they are re-assessed. The initial treatment also includes an exercise programme aimed principally at reducing lumbar lordosis, with training of deep abdominal muscles by co-activation of the lumbar multifidus

proximal to the defect, as well as treatment of hip flexion and hamstring contractures.

There is convincing evidence that tennis players with early stage or progressive lesions of the pars interarticularis should be advised to rest for 2 to 3 months, with the objective of achieving bony union because of the good potential for healing (especially if unilateral), whereas athletes with chronic lesions of the pars interarticularis should be advised to rest for 1 to 2 months, with the aim of relieving low back pain because of the very small chance of achieving bony union.

If patients show no progress with the above programme or if their pain worsens during therapy, we initiate bracing with thoracolumbosacral orthoses. The main advantage of a brace may be in reminding the patient to maintain good posture. Routine, prolonged bracing of all patients with symptomatic spondylolysis is probably not necessary and may pose undue burdens on the patients. The key role of spinal orthotics in the treatment of spondylolysis is reduction of the lumbar lordosis and the device is typically molded at 15° of flexion of the lumbar spine.

It is anticipated that nearly all young athletes can return to sports activity after successful treatment. This suggests that the stability of a fibrous union can be acceptable

LUMBAR SPONDYLOLYSIS IN NUMBERS

- *The volume of the pars interarticularis accounts for only 1.5 cm^{3,27}.*
- *An athlete with prior back injury had a 3× higher risk of injury in the following year than those without previous injury²⁸.*
- *Spondylolysis has an incidence of 5% in the general population but it is much more prevalent in athletes^{8,9}.*
- *Spondylolysis accounts for 47% of all causes of low back pain in the adolescent athlete³.*
- *85% of cases of spondylolisthesis found in children are isthmic-type⁷.*
- *Only 15% of individuals with a pars interarticularis lesion progress to a spondylolisthesis⁷.*
- *80% of low back injuries in athletes occurred during practice³.*
- *SPECT provides 10 to 20× more contrast than planar bone scintigraphy, increasing the sensitivity for pars lesions⁹.*
- *The initiation age of the kick serve in children should be around 12 to 13 years old²⁹.*
- *Approximately 40% of weightlifters have pars injuries²⁴.*
- *75 to 100% of acute pars lesions heal; all unilateral acute lesions heal; 50% of bilateral acute lesions heal but no chronic defects heal⁷.*
- *>90% of children with spondylolysis return to their previous level of activity^{27,30}.*

and there is a low correlation between radiographic healing and clinical outcome.

Most young athletes conservatively treated for early spondylolysis (radiographs negative, nuclear scintigraphy positive) maintained good functional outcome for up to 11 years²⁵.

Surgical intervention may be required in a low percentage of patients, typically when conservative treatment fails. An L5-S1 in situ fusion with autogenous posterior iliac crest bone graft is the standard of care for patients with a symptomatic L5 spondylolysis. Instrumentation is not necessary because the spine is inherently stable. Surgical decompression is indicated when the patient has neural compromise, with a radiculopathy or bowel or bladder dysfunction. A child with a high-grade spondylolisthesis or an adult who does not respond to non-operative care should have surgical stabilisation. An in situ fusion can be successful in many young patients. The long-term results of the different treatment options for high-grade spondylolisthesis are relatively good²⁷.

Preventing recurrence may be difficult for young athletes who wish to return to high-level competitive sports. A maintenance

training programme to preserve spine stabilisation should be incorporated into an athlete's workout regimen. Patients should avoid repetitive hyperextension activities.

SUMMARY

Modern tennis movements require frequent repetitive and rapid rotation of the lumbar spine which predisposes players to acute and chronic injuries. The young tennis player with low back pain presents a clinical challenge for physicians, who must distinguish self-limited from persistent or recurrent symptoms associated with an identifiable pathology. It is accepted that spondylolysis is the most common identifiable cause of low back pain in active adolescents. History and physical examination findings are suggestive but not diagnostic of pars injuries. If the pain is prolonged or severe enough an aggressive imaging work-up for diagnosis should be initiated. Plain radiographs of the lumbosacral spine should be obtained first, but they are usually insufficient for the diagnosis of spondylolysis. The next step is to obtain a SPECT bone scan, because it is the best imaging modality to localise an area of abnormal bone activity.

Other imaging modalities such as CT and MRI may be useful to complete the diagnosis and stage the injury. The serve is considered the tennis stroke imparting the greatest stress on the lumbar spine by a combination of rotation, hyperextension and lateral bending motion. The two-handed backhand is often painful in young players suffering pars injuries, probably due to the forced trunk rotation against a fixed pelvic pivot point. Weight-training exercises, especially explosive Olympic lifts, cause forced hyperextension of the lumbar spine and may increase the risk of pars injuries. The primary aim of the treatment of tennis players with spondylolysis is healing of the pars defect. The majority of patients are successfully treated with conservative measures and maintain a good long-term functional outcome. Surgery may be required in a low percentage of patients. Lumbar spondylolysis is a common and severe injury among young tennis players, which often needs several months for recovery. Prevention should focus on a comprehensive spinal stabilisation training programme and avoiding overuse of lumbar hyperextension and rotation activities.

ACKNOWLEDGMENT

The author thanks Dr Valerie Hindle for her valuable contribution with language editing.

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Available at www.aspetar.com/journal

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