PASIG MONTHLY CITATION BLAST: No.32 **July 2008**

Dear PASIG members:

PASIG member Gina Pongetti contributes this new “food for thought” for your consideration when watching the gymnastics events during the upcoming 2008 Beijing Olympics.

> Core stability is a large part of the sport of gymnastics. In tumbling, vaulting, uneven and high bar skills and especially rings and pommel horse for the men, isometric transversus abdominis strength is of utmost importance. The goal with many tumbling and rebounding skills is “stability” in the core, and motion prevention. Many coaches value traditional conditioning such as sit-ups, v-ups, and hanging strengthening. How would you talk to local gymnastics gyms, and adapt parts of conditioning regimens to increase this isometric demand? How would you explain this to the lay person (parents, athlete) or the coach?
>
> Gina M. Pongetti, MPT, MA, CSCS, ART-Cert.

For the annotated bibliography this month, I’ve selected a relevant topic to gymnastics: *Spondylolysis / Spondylolisthesis*. This month’s citations will be added to EndNote libraries available on the PASIG webpage for our members to access and download. (Information about EndNote referencing software can be found at http://www.endnote.com, including a 30-day free trial). If you’d like to suggest a topic or create one, please let me know. As always, your comments and entry contributions to these Citation Blasts are always welcome.

As always, please drop me an e-mail anytime.

Regards,
Shaw

Shaw Bronner PT, PhD, OCS
Chair, PASIG Research Committee
sbronner@liu.edu

Spondololysis / Spondylolisthesis

The most common cause of low back pain in adolescent athletes visualized on x-ray is *spondylolysis*, a stress fracture that usually affects the 5th lumbar vertebra or, less commonly, the 4th lumbar vertebra. Pain caused by spondylolysis usually spreads across the lower back and may feel like a muscle strain. Extension overpressure causes increased pain. However, Masci et al (2006) reported that the 'one-legged hyperextension test' is neither sensitive nor specific for the detection of active spondylolysis and MRI is inferior to bone scintigraphy (with SPECT)/computed tomography. The defect is seen in the oblique lumbar radiograph: a pars interarticulares defect appears to be a "scotty dog". Differential diagnosis may include a lumbosacral transitional vertebra, articular facet stress fracture, sacral fracture, or sacroiliac joint dysfunction.

Spondylolysis occurs with a prevalence of 4% to 6% in the general population. Although the etiology of this lesion is still unclear, there is an increased prevalence in athletes participating in sports in which participants are subjected to repetitive hyperextension of the lumbar spine. These sports include weightlifting, wrestling, gymnastics, diving, ballet, breast-stroke and butterfly style swimmers, pole vaulting, or collision/contact sports such as football, soccer, hockey, and la crosse.

It is particularly prevalent in the adolescent. Comparison of 100 adolescent athletes with 100 adults with low back pain found that 62% of the adolescents had derangements of their posterior elements and 47% of these had a spondylolysis stress fracture. In contrast, 5% of adult subjects were found to have spondylolysis associated with low back pain. Factors predisposing the young athlete to back injury include growth spurt, abrupt increases in training intensity or frequency, improper technique, unsuitable sports equipment, and leg-length inequality. Other potential risk factors are abnormal menstrual history, dietary deficiencies, and low bone mineral density. Poor strength of the back extensor and abdominal musculature, and inflexibility of the lumbar spine, hamstrings and hip flexor muscles may contribute to chronic low back pain.

Spondylolisthesis occurs in a significant proportion of individuals with bilateral spondylolysis. Predicting risk factors for progression of the slip in spondylolisthesis has proven difficult. Spondylolisthesis can cause spasms that stiffen the back and tighten the hamstring muscles, resulting in changes to posture and gait.

Athletes respond well to non-operative management of these injuries in 80% of cases. This may include bracing to limit extension and unload the posterior elements. A

progression of dynamic spinal stabilization and sport-specific training permit return to competition in the majority of cases.

Shaw Bronner PT, PhD, OCS
PASIG Research Chair

Amari R, Sakai T, et al. (2008). Fresh stress fractures of lumbar pedicles in an adolescent male ballet dancer: Case report and literature review. Arch Orthop Trauma Surg.

Stress fracture in the pars interarticularis is a common cause of low back pain in young athletes. Pedicle stress fractures have also been reported in adolescent sport players, and most of them were associated with contralateral spondylolysis. Only a few cases with bilateral pedicle stress fractures have been reported. We report a 14-year-old ballet dancer with fresh bilateral pedicle fractures treated conservatively, together with a review of the literature.

Baker RJ, Patel D (2005). Lower back pain in the athlete: common conditions and treatment. Prim Care **32**(1): 201-29.

Athletes younger than 12 years of age commonly have pathology related to the lower back pain. Spondylolysis is the most common condition in these athletes. Other conditions, including lumbar Scheuermann's disease, scoliosis, disc herniation, fractures, and muscular stains, can occur. Most of the mature general population experiences low back at some time in life. Athletes may be at increased risk, but outcomes are good. The majority of low back pain in mature athletes is mechanical in nature. Herniated discs, spinal stenosis, sacroilitis, and sacral stress fractures can also cause low back pain in these athletes. Low back conditions mentioned above may be treated with rest, specific exercise programs, and medication. Surgery is indicated for severe spinal stenosis, pain with evidence of neurological compromise, and some painful deformities. Newer treatments for back pain are emerging, but few controlled clinical trials are available.

Bennett DL, Nassar L, et al. (2006). Lumbar spine MRI in the elite-level female gymnast with low back pain. Skeletal Radiol **35**(7): 503-9.

OBJECTIVE: Previous studies have shown increased degenerative disk changes and spine injuries in the competitive female gymnast. However, it has also been shown that many of these findings are found in asymptomatic athletic people of the same age. Previous magnetic resonance imaging (MRI) studies evaluating the gymnastic spine have not made a distinction between symptomatic and asymptomatic athletes. Our hypothesis is that MRI will demonstrate the same types of abnormalities in both the symptomatic and asymptomatic gymnasts. DESIGN: Olympic-level female gymnasts received prospectively an MRI exam of the lumbar spine. Each of the gymnasts underwent a physical exam by a sports medicine physician just prior to the MRI for documentation of low back pain. Each MRI exam was evaluated for anterior apophyseal ring avulsion injury, compression deformity of the vertebral body, spondylolysis, spondylolisthesis, degenerative disease, focal disk protrusion/extrusion, muscle strain, epidural mass, and bone-marrow edema. PATIENTS: 19 Olympic-level female gymnasts (age 12-20 years) were evaluated prospectively in this study. All of these gymnasts were evaluated while attending a specific training camp. RESULTS: Anterior ring apophyseal injuries (9/19) and degenerative disk disease (12/19) were common. Spondylolysis (3/19) and spondylolisthesis (3/19) were found. Focal bone-marrow edema was found in both L3 pedicles in one gymnast. History and physical exam revealed four gymnasts with current low back pain at the time of imaging. There were

findings confined to those athletes with current low back pain: spondylolisthesis, spondylolysis, bilateral pedicle bone-marrow edema, and muscle strain. CONCLUSIONS: Our initial hypothesis was not confirmed, in that there were findings that were confined to the symptomatic group of elite-level female gymnasts.

Bono CM (2004). Low-back pain in athletes. J Bone Joint Surg Am **86-A**(2): 382-96.
While most occurrences of low-back pain in athletes are self-limited sprains or strains, persistent, chronic, or recurrent symptoms are frequently associated with degenerative lumbar disc disease or spondylolytic stress lesions. The prevalence of radiographic evidence of disc degeneration is higher in athletes than it is in nonathletes; however, it remains unclear whether this correlates with a higher rate of back pain. Although there is little peer-reviewed clinical information on the subject, it is possible that chronic pain from degenerative disc disease that is recalcitrant after intensive and continuous nonoperative care can be successfully treated with interbody fusion in selected athletes. In general, the prevalence of spondylolysis is not higher in athletes than it is in nonathletes, although participation in sports involving repetitive hyperextension maneuvers, such as gymnastics, wrestling, and diving, appears to be associated with disproportionately higher rates of spondylolysis. Nonoperative treatment of spondylolysis results in successful pain relief in approximately 80% of athletes, independent of radiographic evidence of defect healing. In recalcitrant cases, direct surgical repair of the pars interarticularis with internal fixation and bone-grafting can yield high rates of pain relief in competitive athletes and allow a high percentage to return to play. Sacral stress fractures occur almost exclusively in individuals participating in high-level running sports, such as track or marathon. Treatment includes a brief period of limited weight-bearing followed by progressive mobilization, physical therapy, and return to sports in one to two months, when the pain has resolved.

Congeni J, McCulloch J, et al. (1997). Lumbar spondylolysis. A study of natural progression in athletes. Am J Sports Med **25**(2): 248-53.
We examined the natural course of athletically active young people with back pain and a diagnosis of spondylolysis (stress fracture of the pars interarticularis of the facet joint of the lumbar spine). We limited the study to those with "subtle" fractures (normal radiographs and positive bone scans) and used computed tomography scanning to further characterize this lesion and to determine whether we could demonstrate healing in this population. The study group included 40 patients with low back pain and a diagnosis of spondylolysis by nuclear medicine study. Computed tomography scans were performed with both traditional cuts and reverse-gantry angled cuts to help determine long-term treatment and prognosis. 45% of patients (18) demonstrated chronic nonhealing fractures, 40% (16) demonstrated acute fractures in various stages of healing, and 15% (6) demonstrated no obvious fractures. With the diagnosis of spondylolysis being fairly common in young athletes with low back pain, primary care physicians need to have a high index of suspicion in making the diagnosis. Computed tomography scans can play a very important role in diagnosis, assessment of the defect, short-term and long-term management decisions, and in determining prognosis.

Connolly LP, d'Hemecourt PA, et al. (2003). Skeletal scintigraphy of young patients with low-back pain and a lumbosacral transitional vertebra. J Nucl Med **44**(6): 909-14.
Lumbosacral (L-S) transitional vertebrae can alter the biomechanics of weight transfer at the affected spinal segment. Low-back pain may result. This study assessed what skeletal scintigraphy reveals about stress associated with a L-S transitional vertebra in young patients with low-back pain. METHODS: The study population included 48 patients (30 male, 18 female; age range, 6-19 y; mean age, 15.7 y) with low-back pain and a L-S transitional vertebra. Skeletal scintigraphy was correlated with plain radiographs in all, CT in

12, and MRI in 11. RESULTS: High uptake was shown at the articulation between the transverse process of a L-S transitional vertebra and the sacrum in 39 (81%) of the patients. In 23 (59%) of the 39 patients with high uptake, this finding was shown only by SPECT. In 13 (81%) of the 16 for which the high uptake was shown by planar imaging, the anterior projection was more valuable than the posterior projection. In 9 (23%) of the 39 patients with high uptake at the transverse-sacral articulation, the L-S transitional vertebra had not been noted in a radiographic report before skeletal scintigraphy but was identified through reevaluation or repetition of radiographs after skeletal scintigraphy. Radiographs showed sclerosis along the transverse-sacral articulation in only 8 (21%) of the 39 patients with high uptake. Findings indicating stress or motion at the joint were shown by CT in 6 (55%) of 11 and by MRI in 5 (63%) of 8 patients with high uptake at the transverse-sacral articulation who underwent these examinations. CONCLUSION: Skeletal scintigraphy often indicates stress at the transverse-sacral articulation of young patients with low-back pain and a L-S transitional vertebra. Showing evidence of stress is best accomplished using SPECT. Changes are usually not radiographically evident, but there is a trend for MRI and CT to show findings that imply stress or motion at the articulation. The unique ability of skeletal scintigraphy to provide this physiologic information supports its use in these patients.

d'Hemecourt PA, Gerbino PG, et al. (2000). Back injuries in the young athlete. Clin Sports Med **19**(4): 663-79.

The diagnosis of back pain in the young athlete should be specific and not attributed to nonspecific, mechanical causes. Risk factor identification and intervention are required. Treatment is then initiated in a specific pattern, addressing flexibility and muscular imbalances. Bracing is often used to allow healing of growth tissue. The lumbosacral orthosis may be molded in a lordotic posture to unload the disc or antilordotic posture to relieve the posterior column; however, customizing the lordosis to the individual biomechanics may be required. Spinal stabilization is initiated with therapy for strengthening isolated weaknesses and progressing to coactivation and proprioceptive techniques, such as the balance ball. Returning to competition is preceded with sport-specific training.

d'Hemecourt PA, Zurakowski D, et al. (2002). Spondylolysis: returning the athlete to sports participation with brace treatment. Orthopedics **25**(6): 653-7.

Between 1988 and 1995, 73 adolescent athletes treated with the Boston Overlap Brace for spondylolysis were reviewed to evaluate improvement in pain score and activity level. A favorable clinical outcome was achieved in 80%. Girls and boys who participated in high-risk sports were five times more likely to have an unfavorable clinical outcome than those who participated in low-risk sports (odds ratio = 5, 95% confidence interval = 2.4-7.5, P = .003). In addition, acute onset of pain and hamstring tightness were associated with a worse outcome. Athletes with symptomatic spondylolysis treated with an antilordotic brace can expect improvement in their clinical course and return to sports participation in 4-6 weeks.

DeMann LE, (1997). Sacroiliac dysfunction in dancers with low back pain. Man Ther **2**(1): 2-10.

SUMMARY. Low back pain is a common occurrence in dancers. Studies have shown its prevalence to be around 12% of all dance type of injuries. It is commonly thought by health professionals who specialize in dance medicine that sacroiliac (SI) dysfunction is one of the more common causes of low back pain in dancers. The aetiology of SI dysfunction in dancers is related to both the biomechanics of the SI joint and the physiological demands placed on the SI joint from the dynamics of dance. Injury to the SI joint can be due to a combination of a single traumatic incident, from overuse factors involving repetitive microtrauma or from emotional stress. Clinical manifestations could be pain in the back, buttock, hip and leg, and limitation of movement specific to dance. Diagnosis is based upon

the deviation from normal of both the static and kinetic functions of the low back and pelvis in its relationship to the biomechanics of dance. Treatment is aimed at relieving pain, restoring the function of the SI joint and returning the dancer to full function.

Featherstone T (1999). Magnetic resonance imaging in the diagnosis of sacral stress fracture. Br J Sports Med **33**(4): 276-7.

Low back and buttock pain in athletes can be a source of frustration for the athlete and a diagnostic dilemma for the doctor. Sacral stress fractures have been increasingly recognised as a potential cause of these symptoms. As plain radiographs are often normal and the radiation load of an isotope bone scan is substantial, the alternative use of magnetic resonance imaging in the diagnosis of a sacral stress fracture is highlighted in this case report.

Fehlandt AF, Micheli LJ (1993). Lumbar facet stress fracture in a ballet dancer. Spine **18**(16): 2537-9.

A frequent cause of back pain in athletes and dancers is stress injury to the posterior vertebral elements. Stress fractures affect the pars interarticularis and, rarely, other vertebral regions. The authors present their experience with the diagnosis and treatment of a fourth lumbar inferior articular facet stress fracture in a ballerina in this brief report and discuss the literature concerning posterior element stress fractures.

Guillodo Y, Botton E, et al. (2000). Contralateral spondylolysis and fracture of the lumbar pedicle in an elite female gymnast: a case report. Spine **25**(19): 2541-3.

STUDY DESIGN: The case of an elite female gymnast whose pathology started in her 12th year and whose evolution has been exceptional is reported. OBJECTIVE: To present a fracture of the right lumbar pedicle showing complete spontaneous consolidation despite gymnastic practice 15 hours a week. SUMMARY OF BACKGROUND DATA: Lumbar pain, which has an incidence of approximately 75% among young athletes, often results from diseases of the posterior arch of vertebrae in gymnasts, including spondylolysis. The association between unilateral spondylolysis and fracture of the contralateral lumbar pedicle in young athletes is poorly described. METHODS: An elite young female gymnast underwent clinical examination and lumbar radiographs (as systematically required by the French Federation for high-level gymnasts) from 1994 to 1997 to join a sports program in gymnastics. RESULTS: Clinical examination and lumbar radiographs systematically required of an asymptomatic female gymnast allowed the condensation of the right pedicle to be observed before lysis of the left isthmus of L5 in 1994, unilateral lysis of the left isthmus of L5 in 1995, a right pedicular fracture of L5 in 1996, and healing of the pedicular fracture in 1997. CONCLUSION: Inconsistency between radiographs and clinical observations can be noted, and spontaneous consolidation of pedicular fractures can occur despite the practice of the gymnastics 15 hours a week.

Hall SJ (1986). Mechanical contribution to lumbar stress injuries in female gymnasts. Med Sci Sports Exerc **18**(6): 599-602.

Because female gymnasts as a group display higher than average incidences of stress-related pathologies of the lumbar spine, it was of interest to evaluate mechanical factors which are potential contributors. Lumbar hyperextension and impact forces were quantified for performances of five commonly executed gymnastics skills by four competitive collegiate women gymnasts. The skills performed were the front walkover, the back walkover, and the front handspring, the back handspring, and the handspring vault. Wielke's (1983) radius method was used to quantify lumbar curvatures from film data during normal relaxed standing postures and during subject performances of the five selected skills. A force

platform was used to monitor vertical and lateral ground reaction forces at the terminations of the respective skill performances. Of the skills examined, the handspring vault produced the highest vertical and lateral impact forces, and the back handspring and back walkover required the greatest amounts of lumbar hyperextension. During the front and back walkovers and during the back handspring, maximum lumbar hyperextension occurred very close to the time that impact force was sustained by either the hands or the feet.

Hutchinson MR (1999). Low back pain in elite rhythmic gymnasts. Med Sci Sports Exerc **31**(11): 1686-8.

BACKGROUND: Rhythmic gymnastics is a sport that blends the athleticism of a gymnast with the grace of a ballerina. The sport demands both the coordination of handling various apparatus and the flexibility to attain positions not seen in any other sport. To attain perfection and reproducibility of their routines, the athletes must practice and repeat the basic elements of their routines thousands of times. In so doing, the athlete places herself at risk of a myriad of overuse injuries, the most common being low back pain. METHODS: To document the presence and severity of low back pain in elite rhythmic gymnasts, a prospective study of seven national team members was undertaken that documented injuries and complaints with daily medical reports over a 7-wk period. These findings were correlated with a retrospective review of 11 elite level gymnasts followed over a 10-month period whose complaints ultimately required evaluation by a physician. RESULTS: Eighty-six percent of the gymnasts in the prospective study complained of back pain at some point over the course of the study. The only injury recorded that required a time loss from sport was a low back injury. The most common complaint requiring a physician's evaluation was low back pain with the diagnoses varying from muscle strains to bony stress reaction or complete fracture of the pars inter-articularis (spondylolysis). No athlete had a spondylolisthesis or ruptured disk. Two had mild scolioses which did not appear to be associated with their low back pain. CONCLUSIONS: It would appear that rhythmic gymnasts are at relative increased risk of suffering low back complaints secondary to their sport.

Johnson AW, Weiss CB, et al. (2001). Stress fractures of the sacrum. An atypical cause of low back pain in the female athlete. Am J Sports Med **29**(4): 498-508.

Low back pain is a common finding in an athletically active premenopausal female population. We describe an unusual cause of persistent low back/sacroiliac pain: a fatigue-type sacral stress fracture. Plain radiographs, bone scans, computed tomography, and magnetic resonance imaging studies were obtained in the female athletes to determine the nature of the pathologic abnormality. The most significant risk factor for fatigue-type sacral stress fractures was an increase in impact activity due to a more vigorous exercise program. Potential risk factors such as abnormal menstrual history, dietary deficiencies, and low bone mineral density were examined. The clinical course was protracted, with an average 6.6 months of prolonged low back pain before resolution of symptoms. Sacral fatigue-type stress fractures did not preclude the athletes from returning to their previous level of participation once healing had occurred.

Kujala UM, Oksanen A, et al. (1997). Training does not increase maximal lumbar extension in healthy adolescents. Clin Biomech **12**(3): 181-184.

OBJECTIVE: To investigate if there is training reserve in the maximal lumbar extension. DESIGN: Three-year longitudinal study. BACKGROUND: Among adults there is variation in the normal range of sagittal motion of the lumbar spine, but reduced spinal flexibility does not predict future occupational back pain. In various sports and in ballet, maximal extension of lumbar spine is a common manoeuvre, and low-back pain is also common. It is not known

whether training increases maximal extension of healthy back. Forceful training of maximal extension may injure the anatomical structures limiting the extension range. METHODS: We compared lumbar sagittal flexibility to hip flexor and hamstring flexibility in a 3-year longitudinal study on female ballet dancers (n = 18), athletes (n = 31), and controls (n = 17) before and after their adolescent growth spurt. RESULTS: Ballet dancers had more flexible hamstrings and hip flexors than controls, but there were no group differences regarding the maximal lumbar flexion or extension. These results persisted throughout follow-up. CONCLUSIONS: The maximal physiological extension of the lumbar spine cannot be increased by training in healthy adolescents. RELEVANCE: An attempt to exceed the physiological maximum extension may only cause overly hard strain on specific anatomical structures of the lumbar spine. This knowledge should be considered when the rules of sports and choreography of dance performances are considered.

Kurd MF, Patel D, et al. (2007). Nonoperative treatment of symptomatic spondylolysis. J Spinal Disord Tech **20**(8): 560-4.

SUMMARY OF BACKGROUND DATA: Symptomatic spondylolysis resulting from a stress fracture of the pars interarticularis is a cause of low back pain in the juvenile and adolescent patient. Treatment is conservative in the majority of cases. OBJECTIVE: To analyze the outcome of patients with symptomatic isthmic spondylolysis treated nonoperatively with a custom fit thoracolumbar orthosis and activity cessation for 3 months followed by an organized physical therapy program. STUDY DESIGN: Retrospective case series. PATIENT SAMPLE: 436 juvenile and adolescent patients with spondylolysis. OUTCOME MEASURES: Pain improvement, hamstring flexibility, range of motion, resolution of back spasms, and return to previous activities. METHODS: Retrospective review of 436 juvenile and adolescent patients with symptomatic spondylolysis confirmed by single-photon emission computed tomography or computed tomography. Clinical outcomes were assessed through patient history and physical examination. RESULTS: Ninety-five percent of patients achieved excellent results according to a modified Odom's Criteria. The remaining 5% of patients achieved good results as they required occasional nonsteroidal anti-inflammatory drugs to relieve pain. Back spasms were resolved and hamstring tightness and range of motion returned to normal in all patients. All patients returned to their preinjury activity level. No patients went on to surgery. CONCLUSIONS: Symptomatic juvenile and adolescent patients with an isthmus spondylolysis may be effectively managed with a custom fit thoracolumbar orthosis brace and activity cessation for approximately 3 months followed by an organized physical therapy program.

Lin JT, Lane JM (2003). Sacral stress fractures. J Womens Health **12**(9): 879-88.

Stress fractures result from skeletal failure resulting from submaximal repetitive forces over time. Sacral stress fractures may represent an underdiagnosed cause of low back and buttock pain. They occur primarily in two populations, young active persons and elderly osteoporotic women, usually corresponding to fatigue and insufficiency-type fractures, respectively. The clinical presentation of these fractures is similar, but the medical and rehabilitation management of these patient populations differs and is tailored to the specific underlying etiology. In both types of fractures, appropriate conservative measures generally result in good functional outcomes. This paper provides an overview of the anatomical considerations, risk factors, clinical presentations, diagnostic imaging findings, appropriate laboratory studies, medical management, and rehabilitation management of patients with sacral stress fractures.

Masci L, Pike J, et al. (2006). Use of the one-legged hyperextension test and magnetic resonance imaging in the diagnosis of active spondylolysis. Br J Sports Med **40**(11): 940-6; discussion 946.

BACKGROUND: Active spondylolysis is an acquired lesion in the pars interarticularis and is a common cause of low back pain in the young athlete. OBJECTIVES: To evaluate whether the one-legged hyperextension test can assist in the clinical detection of active spondylolysis and to determine whether magnetic resonance imaging (MRI) is equivalent to the clinical gold standard of bone scintigraphy and computed tomography in the radiological diagnosis of this condition. METHODS: A prospective cohort design was used. Young active subjects with low back pain were recruited. Outcome measures included clinical assessment (one-legged hyperextension test) and radiological investigations including bone scintigraphy (with single photon emission computed tomography (SPECT)) and MRI. Computed tomography was performed if bone scintigraphy was positive. RESULTS: 71 subjects were recruited. 50 pars interarticulares in 39 subjects (55%) had evidence of active spondylolysis as defined by bone scintigraphy (with SPECT). Of these, 19 pars interarticulares in 14 subjects showed a fracture on computed tomography. The one-legged hyperextension test was neither sensitive nor specific for the detection of active spondylolysis. MRI revealed bone stress in 40 of the 50 pars interarticulares in which it was detected by bone scintigraphy (with SPECT), indicating reduced sensitivity in detecting bone stress compared with bone scintigraphy ($p = 0.001$). Conversely, MRI revealed 18 of the 19 pars interarticularis fractures detected by computed tomography, indicating concordance between imaging modalities ($p = 0.345$). There was a significant difference between MRI and the combination of bone scintigraphy (with SPECT)/computed tomography in the radiological visualisation of active spondylolysis ($p = 0.002$). CONCLUSIONS: These results suggest that there is a high rate of active spondylolysis in active athletes with low back pain. The one-legged hyperextension test is not useful in detecting active spondylolysis and should not be relied on to exclude the diagnosis. MRI is inferior to bone scintigraphy (with SPECT)/computed tomography. Bone scintigraphy (with SPECT) should remain the first-line investigation of active athletes with low back pain followed by limited computed tomography if bone scintigraphy is positive.

McCormack RG, Athwal H (1999). Isolated fracture of the vertebral articular facet in a gymnast. A spondylolysis mimic. Am J Sports Med **27**(1): 104-6.

McTimoney CA, Micheli LJ (2003). Current evaluation and management of spondylolysis and spondylolisthesis. Curr Sports Med Rep **2**(1): 41-6.

Spondylolysis occurs with a prevalence of 4% to 6% in the general population. Although the etiology of this lesion is still unclear, it has been shown to have both hereditary and acquired risk factors, with an increased prevalence in men and athletes participating in certain high-risk sports. Spondylolisthesis occurs in a significant proportion of individuals with bilateral spondylolysis. Predicting risk factors for progression of the slip in spondylolisthesis has proven difficult. Multiple imaging techniques are helpful in the diagnosis of spondylolysis and spondylolisthesis, with recent research addressing the utility of magnetic resonance imaging in the diagnosis and management of pars lesions. The management guidelines have remained largely unchanged since early recommendations. Recently, the addition of a bone growth stimulator to the management of difficult cases has shown promise.

Micheli LJ, Curtis C (2006). Stress fractures in the spine and sacrum. Clin Sports Med **25**(1): 75-88, ix.

Stress fractures of the pars, pedicle, and sacrum are important considerations in the differential diagnosis of lower back pain in the child or adolescent athlete. A thorough history

and physical examination as well as a high index of suspicion are essential when assessing a patient with lower back pain. Diagnostic imaging, including radiographs, bone scans, CT scans, and other imaging modalities are important for further narrowing the diagnosis. The early identification and proper management of stress fractures of the pars, pedicle, and sacrum are integral in the prevention of stress fractures in the adolescent athlete population. This article reviews current concepts in the assessment and management of stress fractures of the lumbosacral spine, particularly of the pars (spondylolysis), pedicles, and sacrum.

Micheli, L. J. and R. Wood (1995). Back pain in young athletes. Significant differences from adults in causes and patterns. Arch Pediatr Adolesc Med **149**(1): 15-8.

OBJECTIVES: To determine whether there are significant differences in the causes of back pain in young athletes compared with the general adult population and to review the diagnosis and assessment of young athletic adolescent patients who present with this complaint. DESIGN: Retrospective randomized case comparison study with two cohorts segregated by age and type of activity. SETTING: The adolescent sports medicine clinic of a children's hospital compared with the acute low back pain clinic of an orthopedic hospital. PATIENTS: 100 adolescent athletes (aged 12 to 18 years; mean age, 15.8 years) with a chief complaint of low back pain were compared with 100 adults (aged 21 to 77 years; mean age, 31.9 years) with acute low back pain. INTERVENTIONS: None. MAIN OUTCOME MEASURES/RESULTS: 62% of the adolescents had derangements of their posterior elements associated with the onset of back pain. 47% of the 100 adolescents were ultimately shown to have a spondylolysis stress fracture of the pars interarticularis. By contrast, 5% of adult subjects were found to have spondylolysis associated with low back pain. Similarly, discogenic back pain was the final diagnosis in 48 of the 100 subjects in the adult group, while 11 of the 100 in the adolescent group had back pain attributable to disc abnormalities. Muscle-tendon strain accounted for back pain in 27% of the adults, while only 6% of the adolescents were diagnosed as having muscle-tendon strain. These differences were significant. Spinal stenosis and osteoarthritis as causes of back pain were encountered in 10% of the adults, while these conditions were not encountered in the children. CONCLUSIONS: There is a significant difference in the major causes of low back pain in young athletes compared with causes of low back pain in the general adult population. Physicians diagnosing back pain in young athletes must have a specific understanding of these differences to avoid incorrect diagnosis and harmful delays in proper treatment.

Sairyo K, Katoh S, et al. (2005). Athletes with unilateral spondylolysis are at risk of stress fracture at the contralateral pedicle and pars interarticularis: a clinical and biomechanical study. Am J Sports Med **33**(4): 583-90.

BACKGROUND: Unilateral spondylolysis is common in youths; its clinical and biomechanical features, especially effects on the contralateral side, are not fully understood. HYPOTHESIS: Unilateral spondylolysis predisposes the contralateral side to stress fracture, especially in athletes actively engaged in sporting activities involving torsion of the trunk. STUDY DESIGN: Case series and descriptive laboratory study. METHODS: Thirteen athletes younger than age 20 with unilateral spondylolysis were included. The contralateral pedicle and pars of spondylolytic vertebrae were examined using computed tomography and magnetic resonance imaging. Using a finite element model of the intact ligamentous L3-S1 segment, stress distributions were analyzed in response to 400-N axial compression and 10.6-N.m moment in flexion, extension, lateral bending, and axial rotation. Unilateral spondylolysis was created in the model at L5. The stress results from the unilateral defect model were compared to the intact model predictions and correlated to the contralateral defects seen in patients. RESULTS: Among 13 patients, there were 6 early-, 2 progressive-, and 5 terminal-stage defects. Three (23.1%) showed contralateral stress fracture. Among

them, 2 belonged to the progressive-stage and 1 to the terminal-stage spondylolysis group. The remaining 4 patients in the terminal defect group showed stress reactions, such as sclerosis at the contralateral pedicle. In the finite element analysis model with an L5 left spondylolysis, the stresses at the contralateral and pars interarticularis were found to increase in all loading modes, with increases as high as 12.6-fold compared to the intact spine. CONCLUSIONS: Unilateral spondylolysis could lead to stress fracture or sclerosis at the contralateral side due to an increase in stresses in the region. CLINICAL RELEVANCE: Surgeons should be aware of possibility of contralateral stress fractures in cases in which patients, especially athletes engaged in active sports, show unilateral spondylolysis and persistent low back pain complaints.

Standaert CJ (2002). New strategies in the management of low back injuries in gymnasts. Curr Sports Med Rep **1**(5): 293-300.

Low back pain is an extremely common complaint in competitive gymnasts, and these athletes are at risk for multiple potential structural injuries to the spine. Of particular concern among gymnasts is spondylolysis. Unfortunately, there are no published, controlled trials on the diagnosis or treatment of spondylolysis in adolescent athletes. However, based on the current literature, there would appear to be little role for the use of plain radiography in the diagnosis of symptomatic spondylolysis; nuclear imaging with single photon emission computed tomography (SPECT) appears to represent the best screening tool for diagnosis. Given the limited specificity of nuclear imaging in the spine, it is generally best to follow any positive study with a limited thin-cut computed tomography scan of the region of concern on the SPECT. Treatment should be based on the radiographic stage of the lesion. Relative rest is an essential component of care. Although the rehabilitation of gymnasts with lumbar injuries is poorly studied, the related literature would support incorporating the concepts of dynamic lumbar stabilization and sport-specific training into their rehabilitation programs.

Tallarico RA, Madom IA, et al. (2008). Spondylolysis and spondylolisthesis in the athlete. Sports Med Arthrosc **16**(1): 32-8.

Spondylolysis and spondylolisthesis are common diagnoses made in the athlete suffering from persistent back pain. Although the etiology of this continuum of conditions is uncertain, genetic predisposition and repetitive trauma have been strongly implicated. Sports in which participants are subjected to repetitive hyperextension across the lumbar spine pose a risk for such injuries. Football lineman, oarsmen, dancers, and gymnasts show high rates of these conditions. Treating the athlete with spondylolysis and/or spondylolisthesis can be a challenge. An inherent drive for return to competition, pressure from coaches and family, and obligations to the team can confound decision making on both the part of the patient and the treating physician. Although this motivation for prompt return to sports must certainly be considered, a safe return to competition is paramount.

Zaman FM, Frey M, et al. (2006). Sacral stress fractures. Curr Sports Med Rep **5**(1): 37-43.

Sacral stress fractures are a relatively common occurrence and can be a debilitating source of low back pain. They generally occur in two distinctly different patient populations, and are of two different etiologies. Sacral insufficiency-type fractures are seen in elderly osteoporotic persons, and fatigue fractures are seen young active individuals. Although the clinical presentation of these fractures is similar, medical rehabilitation and interventional spine management strategies differ according to etiology. Although conservative management strategies have resulted in good outcomes, other treatment options have recently developed. This article provides an overview of the clinical presentation, pathology, and treatment options for sacral stress fractures and discusses some of the recent literature surrounding this interesting topic.