10.5005/jp-journals-10028-1173

REVIEW ARTICLE

Spondylolysis among Fast Bowlers: Approach to Management

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ABSTRACT

Fast bowlers are prone to stress lesions of the pars, especially the young players. The mixed type bowling action and excess bowling workloads are the risk factors associated with this injury. Other factors like adolescent age group, tight hamstrings, lordotic posture and lower limb mechanics have been implicated. Given the heavy cost of time away from play, efforts should be made to prevent these injuries at all levels of the game, across all age groups. Various cricketing boards have laid down guidelines to prevent excess bowling workloads during the match as well as during practice sessions. Coaching interventions are effective in changing the unsafe bowling actions without affecting the bowling speed or performance of the bowler. Spondylolysis may be asymptomatic or present with activity related back pain. A high level of suspicion is required for diagnosis. MRI now seems to be the first line of investigation due to the ability to detect stress reaction of the pars and adjoining pedicle as well as other causes of back pain. Localized CT scan may be required for further characterization of the lesion and to assess healing. Pars lesions have been classified on the basis of MRI picture. Initial stages show only stress reaction (early) followed by cortical breach (progressive) and later appearance of the defect (terminal). Conservative treatment includes rest from sporting activities followed by guided rehabilitation and risk factor analysis. In case of failure of conservative treatment, surgical repair of the pars gives satisfactory results and return to play.

Keywords: Athletes, Brace, Emission-computed, Magnetic resonance imaging, Single-photon, Spondylolysis, Tomography.

How to cite this article: Kothari MK, Shah KC, Prabhoo T, Nene AM. Spondylolysis among Fast Bowlers: Approach to Management. J Postgrad Med Edu Res 2015;49(4):186-193.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Fast bowlers are an integral part of any cricket team. They have formed the lethal attack in the starting as well as the high tension death overs. The bowling action of a fast bowler is an explosive one. The speed of delivery of the ball is a combination of vectors from the spine extension-flexion and shoulder girdle, making it an explosive action which the human body is probably not designed to withstand. Fast bowler is, therefore, most prone to injuries in the sport of cricket comparable to contact sports. Back injuries are one of the common injuries seen in fast bowlers, consisting of injuries of the intervertebral disk, facet joints, pars interarticularis and the soft tissues. Of note, is the injury to the pars interarticularis which forms a vulnerable pivot between the vertebral body and the facet. Although these defects are seen in upto 6 to 11.5% of the normal population,[1] the incidence of this injury is high in fast bowlers. A study on injuries in national and state teams over 10 years, by Cricket Australia reported an average incidence of lumbar spine stress fractures of 0.61 injuries per team per season.[2] Another prospective study reported an incidence of 24%.[3] In a review of literature of MRI-based studies, Arora et al found the prevalence of pars injures in fast bowlers to be between 24 and 81%.[4] Pars injuries are devastating to the fast bowler's career. Long periods of rest are required in the treatment and the time away from play may be up to 2 years.[5] Many a times significant change in the bowling style may be required which may be detrimental to the player's confidence as well as pace. Thus, it seems prudent that risk factor be identified and the knowledge transferred to the on field physiotherapist and coaches.

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RISK FACTORS

Bowling action: There is wide consensus that particular bowling action is a major risk factor for this injury.[6-8] Bowling actions are classified as (a) side-on, (b) front on, (c) semi-open and (d) mixed (Table 1). In the side-on action, the fast bowler has an appearance of bowling 'side-on' as he/she begins the delivery stride, with the left hip and shoulder (in the right hand bowler) pointing toward the batsman.[9] A key feature of a side-on delivery is that it involves the least lumbar spine rotation when compared with other actions. This is the most 'traditional' action, albeit rarely found in modern day fast bowlers.[10,11] In a front-on action, the bowler's hips and shoulders are open before to delivery, giving the appearance of the bowler running straight toward the batsman. This action was

Table 1: Biomechanical characteristics of front-on, side-on and mixed bowling techniques[4]

Bowling technique	*Run-up speed*	*Rear foot position*	*Shoulder alignment at rear foot strike (angle between wickets and line joining shoulder)*
Side-on	Relatively low	Parallel to popping crease	Approximately 180 degrees
Front-on	Higher run up speed compared to side-on	Towards direction of ball travel after release	Greater than 180 degrees
Mixed	Variable run up speed	Transition from front-on to side-on alignment during delivery stride	Transition from front-on to side-on alignment during delivery stride

widely used by the West Indians in the 1970s and 1980s[12] and seen in modern bowlers. The lumbar rotation in this action is less like in the side on action.[13] In the semi-open action the shoulder segment angle lies between the front-on and side-on actions. Similar to both the side-on and front-on actions, there is little to no counter-rotation of the shoulders. It was advocated as a safe technique by the Australian Cricket Board in 1998.[13] In the mixed type, the exact technique can vary as it is a combination of both the front-on and side-on bowling actions. For example, at the back foot contact, the hips and lower limb may adopt an side on orientation whereas the shoulders face front-on to the batsman. However, an opposite of this can also occur.[13,14]

Numerous studies have found the mixed action to be strongly associated with the lumbar vertebral stress injuries.[6,7,13,15] In one study, 89% of players diagnosed with a bony stress injury had a mixed action.[13] Many clinicians believe that the large degree of shoulder counter-rotation in this action is responsible for the stress lesion.[6,7,13] However, some disregard this theory and believe that the large contralateral lumbar side-flexion motion coupled with large ground reaction forces are the real culprits.[16,17] The front-on and semi-open actions have not been implicated as risk factors for injury, most likely due to the lower levels of counter-rotation associated with this bowling style.[14] The side-on action has been traditionally coveted by cricketing authorities, being recognized as the correct way to bowl.[18,19] In pursuit of this action, some bowlers with a front-on technique may have been led to develop the potentially injurious mixed technique.[19] That the ball speed is similar for all actions,[20] bowling style may be changed from a mixed action without any adverse effects on performance, makes clinical screening and technique correction for bowling a viable prevention options.[14] Other factors being studies are height of ball release and extension of the front knee during delivery which needs further evaluation.[14]

PHYSICAL CHARACTERISTICS

Spinal musculature asymmetry, particularly of the quadratus lumborum muscles, is reported by many authors as risk factor for stress fractures of the pars.[21-23] In a prospective study involving 56 male fast bowlers (aged 13–17 years) over 4 years, Engstrom et al reported 11 bowlers who acquired a pars lesion, all at L4 and all 11 bowlers had larger quadrates lumborum muscles on their dominant bowling arm side. The asymptomatic bowlers also had asymmetries, but to a much lesser extent. Bowlers with more than 25% asymmetry have a 58% probability of developing a pars lesion. It is theorized that quadratus lumborum asymmetry increases the shear loading of the pars interarticularis.[21,23] On the other hand, some authors believe that, quadratus lumborum hypertrophy is the consequence rather than a cause of stress lesion of the pars.[24] Morphological features and certain characteristics may also affect the stress generated in the pars. Low medial longitudinal arch of the foot may lead to ineffective force dissipation through the lower limb and ultimately through the lumbar spine.[7,25] Similarly, tight hamstrings, excessive lordotic posture, poor flexibility and general conditioning may play a role in the development of a stress lesion.[26] However, their exact role is not yet elucidated. Recently, Labelle et al introduced the concept of spinopelvic alignment based on pelvic incidence, pelvic tilt and sacral slope.[27] Future prospective studies on young fast bowlers with respect to these parameters may further define the physical risk factors.

OVERUSE

Cadaveric studies based on repetitive mechanical loading of the pars have shown that it is a vulnerable to stress, fatigue and finally failure.[28] Prospective data from one study show that high bowling workload (<3.5 days of rest period between bowling and >2.5 days per week) correlates with injury risk better than total number of deliveries bowled per week (risk ratio 3.1).[29] Orchard et al reported that an abnormal spikes in bowling workload is linked to an increased likelihood of injury 3 to 4 weeks later.[30] Increased workload has also been associated with a change in the bowling action due to fatigue. This may predispose the bowler to stress injuries.[31] There is sufficient data today to suggest that increased bowling workload plays a crucial factor in these injuries. Also, these are easily modifiable factors, unlike the physical characteristics, and hence needs continuous research.

Table 2: Bowling guidelines for the young fast bowler

	England and Wales Cricket Board[34]				*Cricket Australia*[35]			
Age	*Max overs per spell*	*Max. overs per day*	*Sessions per week*	*Balls per session*	*Max. overs per spell*	*Max. overs per day*	*Sessions per week*	*Balls per session*
Less than 13	5	10	2	30	4	8	2	30
U 14 U 15	6	12	2	36	5	10	2	36
U 16 U 17	7	18	3	36	6	16	3	36
U 18 U 19			3	42	8	20	3	42

AGE

Young fast bowlers are at an increased risk of spondylolysis.[3,7,8,32,33] The developing neural arch is not fully ossified between 14 and 30 years of age, which are the prime years of an athlete. The growth cartlilage in adolescents is less resistant to repetitive stress as compared to bone or articular cartilage. Experimental cadaveric biomechanical data show that spines aged between 14 and 30 years showed the greatest susceptibility to fracture through the pars interarticularis.[28] Although this is a nonmodifiable factor but specific protection of this age group can reduce the incidence of this injury.

PREVENTION POLICIES

Given the high 'cost' of away from play period, the value of prevention cannot be overemphasized. Fast bowlers are nurtured from a young age, which is also the age of maximum predisposition for stress lesions of the pars. The younger fast bowlers must therefore be protected from excess repetitive stress. The England and Wales Cricket Board[34] has laid down guidelines for young fast bowlers. Similarly, Cricket Australia[35] has laid down guidelines in their 'junior policy' (Table 2). Research has shown that, young bowlers exceeded the recommended number of deliveries on 42% of training days. Hence, Bowlers need to be monitored during the informal training sessions as well (Table 3). Orchard et al reported a 3 to 4 weeks delay between high workloads and increased risk on injuries, warranting longer scrutiny and probably extended rest periods once increased workloads have been identified. Coaches, parents as well as the players must be educated about bowling workloads. Senior bowlers should avoid too many overs in any single spell and/or avoid bowling too many spells. The coaches must ensure safe bowling action. The mixed type of bowlig action must be identified and corrected. It has been shown that ball speed is similar for all actions.[20] Thus, the change of action would not affect the bowlers performance. This is relevant clinically, because the bowler can be reassured about his performance while decreasing the chances of injury. In a 3 years prospective coaching interventional study, consisting of yearly half-day clinic and six small group coaching sessions, Elliot et al showed that small group coaching significantly reduced the level of shoulder alignment counter-rotation in young fast bowlers.[36] Similar results of coaching interventions in young elite fast bowlers were shown by Ranson et al.[37] In the future further research on the characterization of the bowling technique coupled with morphological characteristics will be able to define the risk factors better and improve prevention strategies and maximize performance.

Table 3: Cricket Australia recommendations for U 14 to U 19 fast bowlers[35]

Match deliveries bowled in a week	*Max. sessions allowed in that week*
11 to 20 overs	2
21 to 30 overs	1
>30 overs	Not allowed to bowl at all

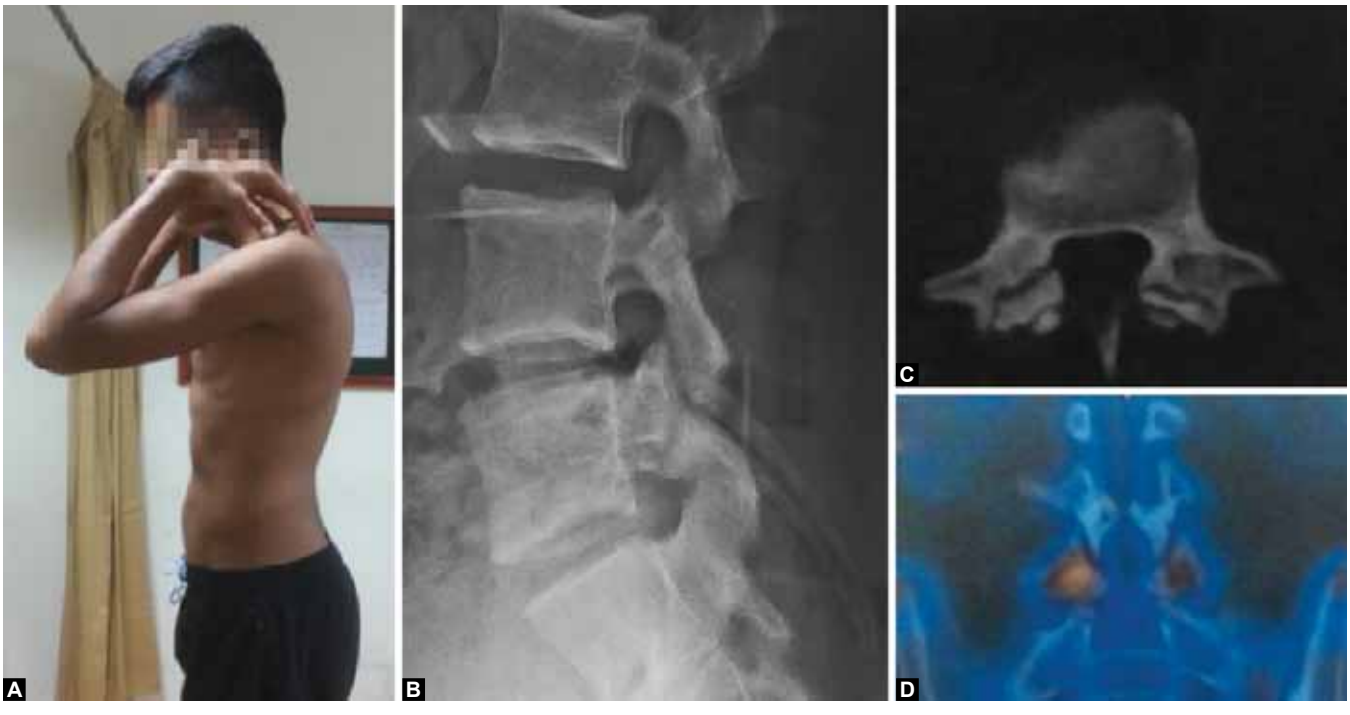
CLINICAL FEATURES

Right handed bowlers tend to develop spondylolysis on the nondominant side, which is subjected to rotation and extension of the back. The L5 level is most commonly affected followed by L4. Most athletes usually present with mechanical low back pain. Crescendo type pain is typical, occurring initially after bowling and subsequently earlier during a spell until the bowler has incapacitating pain and is unable to bowl. A high clinical suspicion is required as the signs may be subtle. Unilateral paraspinal tenderness should raise a suspicion of acute lysis. Spondylolysis may be suggested by the one-legged hyperextension test. However, this test is not reliable and a negative test does not exclude spondylolysis. Associated disk degeneration is hinted by pain on flexion type activities and signs root tension should be sought. Hamstring tightness is also seen.

EARLY DIAGNOSIS

It seems natural that if the impending stress fracture of the pars if picked up and treated early, it would prevent progression to a chronic pseudarthrosis state, which usually requires surgical fusion. Several authors have documented that stress injuries to the posterior elements progress in stages due to repetitive trauma before the changes are seen CT images and still later on

radiographs.[38-41] Technetium-99 m methylene diphosphonate bone scintigraphy is a sensitive test in the diagnosis of pars lesions. It can effectively differentiate an acute pars fracture from a chronic defect. Increase in metabolic activity is seen in cases of acute fractures.[42] Single-photon emission computed tomography (SPECT) is a more sensitive method and better localizes pathology. However, it cannot differentiate between facet arthritis, infection or osteoid osteoma. Therefore, a limited CT imaging should be done for accurate diagnosis (Fig. 1).[43,44] Stress injuries of the lumbar pars produce bone marrow edema visible as abnormal bright T2 signal on sagittal fat-presaturated magnetic resonance imaging (MRI), analogous to stress reactions in other bones. With progress of the stress injury, thinning, fragmentation, or irregularity of the pars is seen on MRI. The final stage of nonunion and sclerosis of the pars defect is easily visible on both MRI and radiographs.[45] Hollenberg et al proposed a 5 grade classification system of increasing severity (Table 4). High signal change in the pedicle on T2W-MRI is an indicator of early spondylolysis has been shown by multiple authors.[46-48] The high signal change has been shown to be associated with favorable outcome after conservative management.[49] With conservative treatment, this high signal change diminishes in most patients by 3 months and correlates with osseous healing as seen on computed tomography (CT).[50] The stage of sclerosis and nonunion (Hollenberg grade V) typically does not heal with conservative management.[49] Magnetic resonance imaging has further advantages of being non-ionizing and non-invasive. It has the ability to accurately diagnose other common lesions, such as herniated nucleus pulposus, degenerated disk, and anular ring lesions, presenting as back pain. Yamane et al[47] advocated the use of dedicated slice to image the pars on MRI. However, Sairyo et al[48] suggested that with just one extra axial section at the level of pedicle, routine MRI sequences are able to identify stress lesion off the pars. They reported no false negative or no false positive cases in their series. Thus, MRI now seems to be the first line of investigation. Campbell et al[51] performed a comparative analysis of CT, SPECT and MRI in patients with spondylolysis. They concluded that MRI should be used as first line investigation for the detection of early stress lesion of the pars. Targeted CT should be performed in patients with acute defects or stress reaction, and in indeterminate cases. Computed tomography also is invaluable as a baseline and follow-up imaging for assessment of healing. Campbell proposed that there is no role of SPECT in the diagnosis of acute stress lesions of the pars. On the other hand, there are several authors which propose that SPECT should be the first investigation due to higher sensitivity than MRI and bone scan.[52-54] However, these comparisons have been based on adult populations and did not use utilize T2W fat suppressed sequences.[51] Additionally, older studies relied on the ability of MRI to detect the pars fracture in routine sequences. In our country, availability of MRI is far better than SPECT or perhaps even bone scan. Not to mention the radiation involved in SPECT. Computed tomography is the investigation of choice in understanding



Figs 1A to D: A 15-year-old fast bowler presented with activity related pain. X-rays showed lysis of L5 which was confirmed on SPECT and CT scan

Table 4: Magnetic resonance imaging classification of the lumbar pars interarticularis. Adapted from Hollenburg et al[45]

	Grade	*MRI appearance of pars interarticularis*
Normal	0	No signal abnormality, intact
Chronic stress reaction	0a	Cortical thickening, fibrotic/sclerotic marrow signal, intact
Subtotal stress fracture	I	Marrow edema ± signal changes in adjacent intact pedicle or articular process
	II	Marrow edema + pars thinning, fragmentation or irregularity on T1 or STIR*
Acute stress fracture	III	Marrow edema + complete unilateral or bilateral spondylolysis
Chronic stress fracture	IV	Complete spondylolysis without marrow edema (chronic united pars fractures)

STIR = Short tau inversion recovery

exact anatomy and morphology of pars defect. On axial CT scan, any discontinuity in neural arch at level of pedicles indicates pars defect. Pars defect and facet joint look similar on CT, therefore it is important to differentiate. Pars defects are irregular with sclerotic margins and without capsular invagination.[55] Computed tomography scan can differentiate between healing stress fracture and reaction of osteoid osteoma which give similar radiographic appearance.[43] It also helps in determining the gap between fractured fragments and presence of fibrous or fibrocartilaginous or osteocartilagenous tissue.[43] Computed tomography can help differentiating acute from chronic fracture, hence influencing management. A pars defect showing wide and sclerotic margins with wide gap indicates a chronic fracture, signifying that it has no potential for union with nonoperative treatment. A pars defect showing narrow and non-corticated margins with no or small gap indicates an acute fracture, signifying that union is possible with immobilization.[56] Plain radiograph is useful in spotting lysis defect; however it is not sensitive to pick up subtle fractures or early prefracture state. Pars defect seen on lateral or posterior oblique radiograph is a direct sign of lysis. However, its absence does not rule out spondylolysis or stress reaction and cannot be relied upon in athletes, where time is precious.

MANAGEMENT

Conservative

Conservative treatment is indicated in cases of acute fracture which has potential to heal. It includes complete cessation of sporting and impact activities for 12 weeks.[56-59] Some authors advocate use of brace which prevents motion at fracture site and aid in healing. Use of antilordotic brace has been used with satisfactory results.[58,59] A standard recommendation of full time wearing (usually more than 20 hours per day) of brace for 3 months is advised with cessation of sporting activities followed by full time wear of brace with certain sporting activities.[58,60] Systematic physical rehabilitation program is started along with bracing. This primarily involves antilordotic exercises, abdominal strengthening exercises and hamstring stretches. A special bowling analysis is done to see specific provocative stresses in particular action and subsequently appropriate measures taken.[61,62] The authors believe that systematic supervised rehabilitation is the key to faster recovery (Fig. 2).

Ranawat et al[62] in a series of 18 cricketers with pars defects treated eight players (one opening pace bowler, three medium pace bowlers, one spinner and three batsmen) with conservative treatment. All the players responded well and returned to full time professional cricket. In a study by Hardcastle,[33] 12 fast bowlers were treated conservatively (eight acute fractures, four chronic fractures). All players eventually played full time sport. Sairyo et al[63] prospectively studied 63 pars defects (classified as: early, progressive, and terminal defect based on CT) in patients younger than 18 years treated using a moulded plastic thoracolumbarsacral orthosis (TLSO). They further classified progressive defects based on short tau inversion recovery (STIR) MRI findings: those with high signal intensity at the adjacent pedicle and those with low signal intensity. They reported union rates were 94, 64, 27, and 0% for the early, progressive with high signal intensity, progressive with low signal intensity, and terminal defects, respectively. Healing was achieved at 3.2, 5.4, and 5.7 months for the early, progressive with high signal intensity, and progressive with low signal intensity groups, respectively.

Operative

Operative treatment is indicated in patients with failed conservative treatment for 6 months or chronic pars

Fig. 2: Principles of rehabilitation[72]

Fig. 3: Buck's fusion

defects at presentation which show no potential signs of healing.[43,60]

Some authors confirm source of pain by administering fluoroscopic guided anesthetic injection (lysis block, facet joint block, selective nerve root block or discogram). This further localizes the source of pain and helps in deciding the modality of surgical treatment.[43,64] Surgical options include: pars repair and spinal fusion. Pars interarticularis repair is recommended in adolescents and young adults with L4 or more proximal lysis with normal intervertebral disk.[65] Various methods of pars repair are described like Scott wiring technique,[66] translaminar screw (Buck's repair),[67] hook wire construct[68] and pedicle screw rod construct.[69] Although technically difficult, Buck's repair (Fig. 3) is the procedure of choice.[69] Spinal fusion is usually performed in patients with L5 lysis or associated degenerated intervertebral disk. Since majority of patients are in younger age group, fusion surgery should be avoided to prevent loss of spinal flexibility and risk of subsequent adjacent segment degeneration.[65] In a study by Hardcastle,[33] ten bowlers with 15 defects were operated with Buck's repair, all returned to fast bowling at various levels eventually. In a study by Ranawat et al,[62] 10 players were operated (nine with bucks repair and one metal removal) with excellent results. One bowler underwent metal removal from a fusion procedure done elsewhere. They attributed this failure to repetitive stress due to bowling action.[70] Buck described intervertebral fusion as a drastic procedure for young active individual.[71]

SUMMARY

Fast bowlers have a high incidence of stress lesions of the pars. Early diagnosis and short period of rest followed by remedial techniques holds the key to prevent the loss precious time in the players career. Prevention strategies must be enforced strictly at all levels of the game to protect the adolescent upcoming fast bowlers from injuries.

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