Magnetic resonance imaging of the lumbar spine in asymptomatic professional fast bowlers in cricket

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Low back injuries account for the greatest loss of playing time for professional fast bowlers in cricket. Previous radiological studies have shown a high prevalence of degeneration of the lumbar discs and stress injuries of the pars interarticularis in elite junior fast bowlers. We have examined MRI appearance of the lumbar spines of 36 asymptomatic professional fast bowlers and 17 active control subjects. The fast bowlers had a relatively high prevalence of multi-level degeneration of the lumbar discs and a unique pattern of stress lesions of the pars interarticularis on the non-dominant side. The systems which have been used to classify the MR appearance of the lumbar discs and pars were found to be reliable. However, the relationship between the radiological findings, pain and dysfunction remains unclear.

Fast bowlers in cricket suffer a specific pattern of stress injury of the pars interarticularis with the 4th and 5th lumbar vertebrae on the non-dominant side to the bowling arm being the most common site of injury. There is an association between a mixed bowling action and radiological abnormalities of the lumbar spine in fast bowlers. A mixed action is characterised by misalignment of the shoulders relative to the pelvis, and counter-rotation of the shoulders from a relatively front-on to a side-on alignment during the delivery stride. This technique is thought to place greater torsional stresses on the lumbar spine than a pure side-on or front-on type of action. Mixed action bowlers also have greater amounts of extension and side flexion of the spine during delivery of the ball. However, the precise mechanism linking the kinematics of the trunk during fast bowling and the pathomechanics of low back injury is yet to be established.

Radiological investigation of stress injuries of the lumbar posterior elements has relied on a combination of radiography, bone scintigraphy (including single photon emission computed tomography (SPECT), and reverse gantry computed tomography (rg-CT). However, these all involve exposure to significant doses of ionising radiation. MRI has increasingly been used in the investigation of a wide variety of spinal abnormalities including marrow oedema of the pars interarticularis, lumbar spondylolysis, spondylolisthesis, disc de-
The normal anatomy of the pars interarticularis can be identified clearly using MRI. Recent studies comparing MRI, CT and SPECT findings in assessing the posterior elements have concluded that MRI is reliable in identifying abnormality of the pars interarticularis.\textsuperscript{29-37} Classification systems for defining MRI changes in stress injuries in the lumbar posterior elements in young athletes\textsuperscript{38} (Table I) and for assessing lumbar disc degeneration\textsuperscript{31} have been evaluated and found to be both reproducible and reliable. The disc grading system shown in Table II is a 5-point scale based on the intensity of the MRI signal, the structure of the disc, the distinction between the nucleus and the annulus, and the height of the disc. Good intra- and inter-exam-
iner agreement was found with this classification system based on an assessment of over 300 lumbar intervertebral discs.\textsuperscript{31}

Most studies which have investigated radiological abnormalities of the lumbar spine in fast bowlers in cricket have examined groups of junior elite cricketers. We have compared the MRI findings of the lumbar discs and pars interarticularis in a group of asymptomatic professional fast bowlers and in age-matched healthy, active controls. The intra- and inter-observer reliability of the MRI grading systems for the pars interarticularis and intervertebral discs were also assessed.

### Patients and Methods

Thirty-six male professional fast bowlers, who were free of low back pain in the previous three months and at the time of testing, formed the study group. The control group comprised 17 age-matched, male athletes. The mean (SD) age, height and weight of the fast bowlers were 26 years (SD 4), 186 cm (SD 6) and 84 kg (SD 7), respectively. The mean (SD) age, height and weight of the control subjects were 25 years (SD 5), 182 cm (SD 5) and 79 kg (SD 11), respectively. Testing took place at the end of the professional cricket season, during which all subjects in the fast bowling group bowled during matches or training sessions on an average of at least three days per week. The control subjects all participated in approximately two hours of physical activity, three times a week. Their main sports were soccer (four), backs in amateur rugby (five), gym-based weightlifting and cardiovascular exercise (seven) and swimming (one). Excluded were athletes with a previous low back injury resulting in the inability to participate in physical activity for greater than one week, previous surgery to the low back and regular participation in cricket or other one-sided activities such as racket or throwing sports. Ethical approval for the study was given by the Local Region Ethics Committee.

The study and control groups were both scanned on a GE Medical Systems 1.5 Tesla MR scanner (General Electric Medical Systems, Milwaukee, Wisconsin) using a standard protocol. This comprised sagittal and axial T1-weighted and sagittal short tau inversion recovery (STIR) sequences, the sagittal sections covered out to the lateral border of the lower lumbar posterior elements and were of 3 mm thickness. The sequence parameters were TR 500, TE 13 ms for the T1-weighted images; TR 8000, TE 50, T1 130 ms for the STIR images. The axial T1-weighted sections were obtained in a block extending from the superior vertebral endplate of L4 down to the inferior vertebral endplate of S1.
The MR scans were assessed independently by two experienced musculoskeletal radiologists using classification systems adapted from Hollenburg et al\textsuperscript{38} (Table I) and Pfirrman et al\textsuperscript{31} (Table II) for the pars interarticulares and discs, respectively. Each radiologist, blinded to the results of the other examiner, performed the classifications twice within a three-week period. Following assessment of the inter- and intra-examiner reliability, any discrepancies in the classifications were resolved by mutual agreement.

**Statistical analysis.** Descriptive statistics were used to describe the abnormal radiological features. Kappa co-efficient and percentage of agreement statistics were used to quantify the reliability of the classification systems for the intervertebral disc and pars interarticulares.

**Results**

**Lumbar pars interarticularis.** The results of the grading of the lumbar pars interarticulares for the dominant and non-dominant side for both the fast bowlers and control subjects are shown in Figure 1. The fast bowlers had a much higher prevalence of abnormalities (129) on the non-dominant side compared to the controls (6) (81% vs 36%), whilst 81% of the pars on the dominant side appeared normal at all levels in the fast bowlers. The most common abnormality seen in the fast bowlers was a multiple level chronic stress reaction of the pars interarticulares on the non-dominant side (grade 0a) seen in 19 (53%) bowlers, followed by chronic stress fracture (grade IV) in five (14%) and sub-total stress fracture (grades I and II) in five (14%). In the fast bowlers, six of the seven chronic stress fractures were at L5, with two bilateral and two unilateral on the non-dominant side, and one was at L4. In comparison, chronic stress reactions were more common on the dominant side (four; 24%) as opposed to the non-dominant side (two; 12%) in the controls. None of the controls had sub-total stress fractures (grades I and II) on either side and...
12% had bilateral chronic stress fractures (grade IV), all at L5. None of the fast bowlers or controls had the MR appearance of an acute stress fracture of the pars interarticularis (grade III).

Figure 2 shows the distribution by lumbar level of the MR appearances of the pars interarticularis in the fast bowlers. The majority of abnormalities were seen at the lower levels on the non-dominant side.

One of the fast bowlers had the MRI changes of a cystic lesion at the zygapophyseal joint of L2/3 on the non-dominant side with a localised lesion at the tip of the associated inferior articular process of L3. Subsequent CT scanning revealed an un-united fracture of this inferior articular process. Chronic stress changes were evident in the posterior bony elements from L2 to L4 bilaterally and the zygapophyseal joints from L2 to L5 were moderately arthritic.

Lumbar intervertebral disc. The grading of the appearance of the lumbar intervertebral discs on MRI in the control subjects and the fast bowlers is shown in Figure 3. Of the fast bowlers, 22 (61%) had MRI abnormalities of the intervertebral disc in at least one lumbar level compared to nine (53%) of the controls. However, 12 (33%) fast bowlers compared to two (12%) in the control group had severe lumbar disc degeneration (grades IV and V), with six (17%) fast bowlers having severe degeneration at multiple levels. A further six (17%) fast bowlers and six (36%) in the control group were graded as having moderate disc degeneration (grade III) at one or more levels. None of the controls and 4 (11%) fast bowlers had mild disc degeneration (grade II). The majority of degenerative discs were found at the L4/5 and L5-S1 levels in both the fast bowlers (25 of 40 degenerative discs; 62%) and the control group (9 of 10 degenerative discs; 90%).

Relationships between the MRI appearance of the lumbar intervertebral discs and the pars interarticularis. Only three (8%) fast bowlers, compared with four (24%) controls, had a normal MR appearance of both the intervertebral discs and pars interarticularis at all lumbar levels. Half of the fast bowlers (12 of 24) who had stress injuries of the pars interarticularis at multiple levels did not have any evidence of disc degeneration. All five of the fast bowlers, but only two (50%) of the controls, who had chronic stress fractures had concurrent severe disc degeneration.

Reliability of the classification systems of the MRI appearances of the disc and pars interarticularis. The Cohen kappa coefficient and percentage agreement statistics for the lumbar intervertebral disc grading indicated that there was substantial reliability of the intra-examiner classification (0.6, 90%) and moderate reliability of inter-examiner classification of the discs (0.5, 87%). There was substantial reliability of both the intra-examiner (0.7, 96%) and inter-examiner (0.6, 95%) for the classification of the pars interarticularis.

Discussion

Lumbar pars interarticularis. Several authors have proposed that stress injuries to the posterior elements develop in stages with repetitive trauma until the changes are detectable on radiographs or CT images. The early stages seen on MRI such as bone marrow oedema (grade I) and oedema with thinning and fragmentation of the pars (grade II), had a prevalence of 22% in the fast bowlers. There was a high prevalence of multi-level cortical thickening along with sclerosis and marrow fibrosis of the pars interarticularis on the side opposite to the bowling arm. Identification of such changes has not been reported in previous MRI studies of the pars interarticularis. Their identification in this study was probably aided by the marked asymmetry of the appearances in individual subjects, enabling ready comparison with the opposite side. Elliott et al carried out CT scans on a group of 20 fast bowlers with a mean age of 17.9 years and found sclerosis of a pedicle at L4 or L5 in 30%, suggesting an evolving or resolving stress fracture. However, it is not known whether this type of lesion, termed ‘chronic stress reaction’ in this paper, is a precursor to acute stress fracture or simply a normal bony adaptation to the
repeated asymmetrical stresses placed on the posterior elements of the lumbar spine by fast bowling.26

The responses to bone stress, traditionally identified with SPECT,43 can also be identified with MRI, supporting the view of Campbell et al37 that SPECT scanning does not have a role in the investigation of these types of injuries. Chronic stress fractures can also be identified on MRI. However, as demonstrated in the case cited in this study, subsequent CT scanning may be needed to provide more precise imaging of the bony architecture.

Gregory et al43 stated that ununited stress fractures may require operative stabilisation in the presence of ongoing back pain in fast bowlers. The results of this study support the findings of a CT study by Millson et al44 which showed that fast bowlers can be asymptomatic despite having ununited lumbar stress fractures. Five asymptomatic fast bowlers in this study had chronic stress fractures. Other possible sources of low back pain should be excluded before progressing to operative stabilisation of chronic stress fractures. That none of the fast bowlers or asymptomatic controls in this study had evidence of acute complete lumbar stress fracture, may indicate that it is the acute stress injuries which cause pain and limit sporting activity.

Both the fast bowlers and controls had a similar prevalence of chronic stress fracture to that previously seen in athletes of a similar age.11 Interestingly, in the control subjects all chronic stress fractures were bilateral at L5, whilst two of the fast bowlers (6%) had bilateral chronic lesions at L5 and three others had unilateral fractures on the non-dominant side. Although it is not possible to identify which of the bilateral stress fractures were developmental as opposed to those which may have arisen as a result of sporting or occupational activities, it is highly likely that the unilateral fractures in the fast bowlers were caused by that activity.

The relationships between the MR appearance of the lumbar intervertebral disc and the pars interarticularis. It has previously been suggested that a loss of height of a disc associated with degeneration leads to increased stress being placed on the posterior bony elements of the lumbar spine.6,9 However, a high proportion (50%) of the fast bowlers in this study who had chronic stress reaction and subtotal stress fracture had a normal height and appearance of the disc. Also, half of the 24% of control subjects who had chronic lumbar stress fractures did not have evidence of disc degeneration. The fact that all chronic bilateral stress fractures in fast bowlers were associated with severe disc degeneration at that spinal level could indicate that an excess of segmental motion caused by an un-united fracture had precipitated disc degeneration.

Reliability of the MRI disc and pars interarticularis classification systems. Although not achieving kappa co-efficient scores as high as the original authors,31,38 both the adapted classification systems for the pars interarticularis and the intervertebral disc used in this study had acceptable reliability and could be useful tools for the staging and re-assessment of injuries to these sites in athletes.

Fast bowlers in cricket have a high prevalence of multi-level chronic stress reactions and injuries of the pars interarticularis on the non-dominant side. Disc degeneration is also present in higher proportions than in non fast bowlers. However, disc degeneration is not a necessary precursor to lumbar stress injury. Fast bowlers can continue to bowl with chronic lumbar stress fractures although continuing to do so with bilateral stress fractures may precipitate severe disc degeneration. The clinical relevance of MRI abnormalities is not clear and further prospective studies, possibly using dynamic imaging modalities, are required to establish the relationship between pain, function and pars interarticularis and disc findings.

Supplementary material

A further opinion by Mr Frank Horan and Mr Simon Shepherd is available with the electronic version of the article on our website at www.jbjs.org.uk

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

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