Disk degeneration and fast bowling in cricket: an intervention study

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ABSTRACT

ELLIOTT, B., and M. KHANGURE. Disk degeneration and fast bowling in cricket: an intervention study. Med. Sci. Sports Exerc., Vol. 34, No. 11, pp. 1714–1718, 2002. Purpose: The purpose of this study was to identify the relationship between the incidence of lumbar disk degeneration and bowling technique after 3 yr of educational intervention. Methods: Two groups of cricketers from the Western Australian fast-bowling development squads acted as subjects in this longitudinal study. Group 1 comprised 24 fast bowlers, of mean age 13.4 yr at the commencement of the study. They attended at least three of the four yearly testing sessions between 1997 and 2000. A further 17 of mean age (in 1998) of 13.2 yr attended a minimum of two of three yearly testing sessions between 1998 and 2000, and comprised group 2. Players were filmed laterally and from above by two video cameras during each testing session. Specific technique variables that previously had been linked with an increased incidence of lumbar disk abnormalities were measured from the videos. Magnetic resonance imaging (MRI) scans of the lumbar disks of each player were also recorded at approximately the same time. A yearly half-day clinic and six small group coaching sessions spread over the season were held to assist the bowlers develop techniques that had been linked with a reduction in back injuries. Results: Data showed that small group coaching significantly reduced the level of shoulder alignment counter-rotation in young fast bowlers. The incidence and progression of lumbar disk degeneration were also significantly reduced in parallel with this decreased shoulder counter-rotation. Conclusion: Technique assessment and modifications through an educational process aimed at reducing mechanical features that have been linked to back injury decreased the incidence and/or progression of lumbar spine disk degeneration. Key Words: EXERCISE PROMOTION, BIOMECHANICS, LUMBAR SPINE, MRI, EDUCATION, YOUTH SPORT

Research that identifies causal mechanisms associated with injury inevitably requires the combined resources of specialists such as biomechanists, exercise physiologists, epidemiologists, physicians, and physical therapists. Winston et al. (18) proposed that biomechanics should be an integral part of what they termed epidemiological research if injury control mechanisms were to be understood. This is essential as most injuries have a mechanically related etiology (17).

Van Mechelen et al. (15) reviewed risk factors involved in sport and suggested a four-step prevention process, namely:

1. Base research hypotheses on epidemiological data (nature, extent and severity of injury).
2. Identify the etiology of the problem.
3. Educate the relevant population as to the injuries inherent in that sport and the techniques needed for prevention.
4. Evaluate the effectiveness of the preventative measures.

Epidemiological data have shown that the greatest injury risk was among schoolboys (47.4% per year; 14) and A-grade or provincial fast bowlers (42% per year; 13). The most common injury site was the back with incidences of 33.3% and 17%, respectively. Elliott et al. (4) reported that a group of 18-yr-old, high-performance fast bowlers displayed 55% bony (spondylolysis and/or pedicle sclerosis) and/or 65% intervertebral disk abnormalities to the lumbar vertebrae.

A prospective study of fast bowlers identified the etiology of these back injuries (7). A significant association was found between transverse plane counter-rotation of the shoulder alignment (line joining the acromion processes) of approximately 40° (0.7 rad) and an increase in lumbar spondylolysis and soft tissue injuries over one season (7). The incidence of bony abnormalities and disk degeneration was again significantly related to transverse plane counter-rotation of the shoulder alignment by greater than 20° (0.35 rad) in the bowling action (2,4). Bowlers who delivered the ball from a greater relative release height also were more likely to sustain a back injury (7). A longitudinal study by Portus (11) of elite fast bowlers reported a mean transverse plane counter-rotation of the shoulder alignment of 41° (0.72 rad). This was the only technique characteristic to be statistically linked to an increased incidence of lumbar stress fractures.

There is a paucity of randomized control studies that have investigated either reduced injury rates or improved performance after an educational program. One study used an educational intervention in an attempt to reduce the incidence of back injuries and modify bowling technique. A
group of young bowlers (mean age = 13.6 yr) who attended a half-day educational seminar with coaches and parents after testing significantly increased their incidence of lumbar disk degeneration from 21% to 58% over a 2.7-yr period (2). The seminar provided coaches, parents, and fast bowlers with information on the dangers inherent in using an action that included greater than 0.35 rad (20°) transverse plane counter-rotation of the shoulder alignment and provided them with coaching literature to reinforce “safe techniques.” No specific small-group coaching or educational follow-up occurred after the seminar.

Grimshaw and Burden (9) used a different educational approach to modify technique and reduce the incidence or level of injury/pain experienced in golf. After electromyographic and motion analyses of technique, an intense 3-month training program (technique and physical capacities) was administered to a professional golfer who was unable to play without pain. Modification to technique and improved physical capacities then enabled the golfer to play successfully without pain.

This study sought to quantify changes in the incidence of lumbar disk degeneration, which was assessed by MRI in young bowlers over a 4-yr period. Bowling technique, transverse plane shoulder alignment counter-rotation, and front-knee joint angle during the delivery stride also were related to the above level of degeneration. During this time, all fast bowlers were counseled as to the possible causes of back injury via an annual seminar and a series of coaching sessions (6 per year) aimed specifically at reducing the level of shoulder alignment counter-rotation.

DEFINITION OF TERMS

Bowling definitions at back foot impact during the delivery stride (Figs. 1 and 2) (3):

**Side-on action.** A shoulder alignment of equal to, or less than, 190° and a back foot angle of equal to, or less than, 280° (Fig. 1A); 180° is a shoulder/foot alignment parallel with the pitch (direction of delivery), whereas 270° is a shoulder/foot alignment perpendicular to the pitch (Fig. 2). Shoulder counter-rotation must be less than 20°.

**Front-on action.** A shoulder alignment of greater than 190° and a back foot angle of greater than 280° (Fig. 1B). Shoulder counter-rotation must also be less than 20°.

**Mixed action.** Shoulder alignment of greater than 190°, any foot placement, and a counter-rotation of the shoulders of greater than 20°.

**RADIOLOGICAL DEFINITIONS**

**MRI.** A technique in which an image is formed of the intervertebral disk based on its water content.

**Intervertebral disk degeneration.** A process where the hydrated intervertebral disk is progressively converted to an anhydrous body (Fig. 3).

**Peripheral annular bulge.** The peripheral component of the intervertebral disk (the annulus fibrosus) extends beyond the margin of the vertebrae (see Fig. 3).

**METHODS AND PROCEDURES**

**Source of the data.** Twenty-four male members of the Western Australian Cricket Association fast-bowling development squad of mean age 13.4 yr in 1997 attended three of four yearly testing sessions between 1997 and 2000 (group 1). A further 17 fast bowlers (mean age = 13.2 yr in 1998) from the same cricket association attended two or three yearly testing sessions between 1998 and 2000 (group 2). At the time of testing, no bowler had any knowledge of abnormal radiological features, and all were bowling without pain. After approval by the University of Western Australia Human Ethics Committee, signed informed consent was obtained from the participant and a parent/guardian before participation.

**Data collection procedures.** Biomechanical data were collected after a thorough warm-up and after each
The highest velocity trial, as identified from the sagittal-view video, was selected for analysis. The video-based 2D estimation of the transverse plane shoulder alignment was calculated by creating a line-of-best-fit between the acromion processes from the overhead camera view using Silicon Coach software (Sport and Physical Education Technology Ltd., Otago, New Zealand). In this procedure, a skilled researcher ignored excessive movement of an acromion process when digitizing the general alignment of the shoulders. This representation of the transverse plane alignment of the shoulders has been shown to accurately reflect the acromion alignment calculated in 3D, projected onto the transverse plane at the phases of the action where the measures were recorded (6). It also accurately represented the transverse plane projection of the thorax alignment (7th cervical vertebra, xiphoid process, and suprasternal notch of the sternum) (6) over the above period. All transverse plane angular measures were relative to the pitch alignment in the direction of bowling, measured in an anticlockwise direction, as shown in Figure 2. Maximum included knee joint angle of the front-leg was calculated from the laterally positioned camera, using the same analysis software.

Maximum knee flexion angle and shoulder alignment counter-rotation were calculated at back- and front-foot impacts, and at the position of maximum counter-rotation. Bowling technique (side-on, front-on, or mixed) at each testing session was categorized as defined above.

The same radiographer assessed each scan, blinded, over the 4 yr of the study. This visual inspection was based on experience and allowed each bowler to be placed into one of two categories (normal or abnormal radiological appearance of the disk, such as disk degeneration or bulging). If degeneration was evident, then the previous scan was reviewed to assess whether progression had occurred over the 1-yr period.

**Coaching intervention.** A coaching clinic was held in conjunction with each testing session to emphasize the importance of bowling technique and physical preparation. All players were encouraged to adopt the front-on or side-on bowling technique. Parents/guardians and coaches were also educated as to the dangers of bowling with a mixed action.

Six coaching sessions were organized by the Western Australian Cricket association each year for both groups of bowlers. At these sessions, video was used to provide visual feedback on the bowling action of each participant. The need to reduce transverse plane counter-rotation was again emphasized.

No control group was employed, as there is evidence showing that making no changes in shoulder counter-rotation by mixed action bowlers will lead to concomitant increases in disk degeneration with no intervention strategy (2).

**Statistical analysis.** Data from the two groups were pooled by age such that group 1 in 1997 was combined with group 2 in 1998 to form year 1 of the longitudinal study. This meant that only group 1 members comprised year 4 of the study (2000).

Repeated measures analyses of variance (age/year of intervention) were conducted to determine main effect changes in maximum shoulder counter-rotation and maximum front knee angle during the delivery stride. Tukey’s post hoc comparisons were used to determine where changes actually occurred if a significant main effect was recorded.

A chi-square was used to test for changes in disk degeneration status. Evidence of degeneration before the first year of intervention together with classification of bowling action enabled bowlers to be categorized into side-on/ front-on or mixed actions and normal or degenerated disk status. At each subsequent testing session, bowling action was again assessed along with disk status. The above process was followed because bowlers could alter their action, and not record a progression in the degenerative process, but still record a degenerative MRI scan. Hence, each case was also treated separately over the 3 or 4 yr of the study. As a result...
of the number of separate comparisons, significance was set at an alpha level of 0.01, to minimize the prospect of a difference being accepted by chance.

RESULTS

The coaching intervention was shown to have no significant influence on the maximum front-knee joint angle recorded over the 4 yr of the study ($F = 1.5560; P = 0.2029$) (Table 1). A mean knee angle of $15.2^\circ$ across all conditions, and a range over the years of the study of $13.3^\circ$–$16.4^\circ$, was recorded.

However, a significant main effect was recorded ($F = 8.3505; P = 0.004$) in the level of transverse plane shoulder alignment counter-rotation over this period (Table 1). Significant reductions were recorded between year 1 ($35.4^\circ$) and years 3 ($24.8^\circ$) and 4 ($21.3^\circ$). The number of bowlers who used the mixed action reduced in parallel with this reduction in shoulder counter-rotation. This reduction was from $80.5\%$ in the first year, to $60\%$ and $33\%$, respectively, for years 3 and 4 (Table 2). Ball velocity was not influenced by the action used. The front-on/side-on bowlers increased from $88.3$ to $103.8$ km·h$^{-1}$ over this period, whereas the mixed action group increased from $89.1$ to $105.1$ km·h$^{-1}$.

Bowlers who used a front-on or side-on action had, by definition, lower levels of transverse plane shoulder counter-rotation and recorded significantly lower levels of lumbar disk degeneration when compared with the mixed action bowlers (chi-square value $= 9.5126; P = 0.002$). The 143 scans recorded over the four annual testing periods were all related to the bowling action at the time of the scan. Of the 49 players who used the front-on or side-on actions, only one sustained a lumbar disk abnormality. However, of the 94 linked to the mixed action, 20 recorded degeneration of a lumbar vertebra.

Twenty-seven percent of those bowlers who used a mixed action recorded a lumbar disk degeneration in year 1 of the study when compared with the $12.5\%$ for the side-on/front-on group. Progression of the number and/or severity of degeneration only occurred with bowlers who used the mixed action (Table 2).

DISCUSSION

Although not as severe as a pars interarticularis abnormality, degeneration or bulging of an intervertebral disk may cause pain and alter the distribution of forces acting on the vertebrae (16). Disk degeneration, which generally starts during the second decade of life, is known to increase naturally with age (8,10,12). However, this increase is more pronounced in a population of cricket fast bowlers, where mechanical loading of the lumbar region occurs during the bowling action (2). Disk degeneration has been reported to increase from $21\%$ to $65\%$, at 13 and 18 yr, respectively (2,4) and was reported as high as $70\%$ in retired elite fast bowlers (1).

The incidence level of lumbar vertebra degeneration for 13- to 14-yr-old fast bowlers has been reported as approximately $20\%$ (5). This level has been shown to increase dramatically to $58\%$ over a period of $2.7$ yr (13.6–16.3 yr) if transverse plane shoulder counter-rotation was not reduced (2). Burnett et al. (2) attempted to reduce counter-rotation by intervening with a coaching seminar after the first test period.

In this study, a similar degeneration level of $24.4\%$ was recorded for the youngest group of bowlers of mean age 13.3 yr. Therefore, one could assume that disk degeneration could have progressed to a similar or higher level in this study, if excessive shoulder counter-rotation was retained in the bowling action. However, a reduced incidence or progression of degeneration was recorded (33%: Fig. 4) over the 4 yr of the study, when compared with Burnett et al. (2). The greatest increase in the occurrence of degeneration is seen between years 1–2, showing that the intervention needed more than 1 yr of coaching to be viable.

The $35.4^\circ$ transverse plane counter-rotation of the shoulders at the commencement of the study was similar to levels that have been linked with both lumbar disk and pars interarticularis abnormalities (4,7,11). No significant decrease in mean shoulder alignment counter-rotation was recorded after 1 yr of intervention. The similar counter-rotation measures (year 1 = $35.4^\circ$; year 2 = $31.1^\circ$) over the first two testing sessions were associated with the largest increase in lumbar disk degeneration (Fig. 4). The level of shoulder counter-rotation at year 1 significantly reduced to $24.8^\circ$ and $21.3^\circ$ after 2 and 3 yr of intervention, respectively. How-

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**TABLE 1. Maximum data recorded during the bowling action (*) (mean ± SD).**

<table>
<thead>
<tr>
<th>Kinematic Variables</th>
<th>Year 1 (N = 41)</th>
<th>Year 2 (N = 41)</th>
<th>Year 3 (N = 40)</th>
<th>Year 4 (N = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder alignment counter-rotation</td>
<td>35.4 (13.1)</td>
<td>31.1 (10.8)</td>
<td>24.8* (11.4)</td>
<td>21.3*† (9.3)</td>
</tr>
<tr>
<td>Front-knee angle</td>
<td>13.3 (5.4)</td>
<td>16.4 (8.6)</td>
<td>15.3 (8.5)</td>
<td>15.9 (6.1)</td>
</tr>
</tbody>
</table>

* Significantly different from year 1 level.
† Significantly different from year 2.

**TABLE 2. Bowling action classification and disk status (number with degeneration those with an increased degeneration).**

<table>
<thead>
<tr>
<th>Year</th>
<th>Year 1 (N = 41)</th>
<th>Year 2 (N = 41)</th>
<th>Year 3 (N = 40)</th>
<th>Year 4 (N = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front-on/side-on</td>
<td>8</td>
<td>11</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Disc status</td>
<td>1</td>
<td>1 (0)</td>
<td>3 (0)</td>
<td>3 (0)</td>
</tr>
<tr>
<td>Mixed</td>
<td>33</td>
<td>30</td>
<td>24</td>
<td>7</td>
</tr>
<tr>
<td>Disk status</td>
<td>9</td>
<td>12 (5)</td>
<td>10 (6)</td>
<td>4 (2)</td>
</tr>
</tbody>
</table>

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**Figure 4—Disk degeneration compared with data from Burnett et al. (2).**
ever, this mean value was still above the classification level for the mixed bowling action (20°).

The percentage of bowlers who were changed from the “injury prone” mixed action to using “safe” front-on or side-on bowling actions was significantly increased from 19.5% to 66.7% after the 3 yr of education and coaching interventions. Of those bowlers who initially used the front-on or side-on actions, only one sustained a lumbar disk abnormality. No bowlers who displayed an abnormal lumbar disk and switched from the mixed action to a front-on or side-on action displayed any progression in the level of degeneration. All bowlers who either developed a new degeneration or displayed a progression of a current condition bowled with a mixed action. It was also important to note that ball velocity was not influenced by the action used. The front-on/side-on bowlers increased from 88.3 to 103.8 km·h⁻¹ over the 4-yr period, whereas the mixed action group increased from 89.1 to 105.1 km·h⁻¹.

The maximum knee joint angle during the delivery stride did not alter over the period of the study. Foster et al. (7) advocated that bowlers should flex the knee joint at impact to assist in the dissipation of the ground reaction forces and reduce the likelihood of sustaining a back injury. The mean knee joint flexion of 15.2° for the 4 yr was similar to the 13.3° reported by for injury-free young fast bowlers of similar ability (5).

**CONCLUSION**

Sport biomechanists interested in injury reduction should broaden their approach to research design to include all phases of the model proposed by van Mechelen (15). A 3-yr intervention comprising small group coaching and an annual seminar effectively reduced the level of shoulder counter-rotation and controlled the level of disk degeneration for young fast bowlers. This approach required greater than 1 yr to achieve these results. However, as 33% of the subjects retained counter-rotation of the shoulders beyond a recommended level after 3 yr of intervention, it is apparent that individual coaching of a more specific and intense nature is required when aiming to reduce the incidence of injury in young, high performance sports people.

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**REFERENCES**


