Three-Dimensional Trunk Kinematics and Low Back Pain in Elite Female Fast Bowlers

Max C. Stuelcken, René E.D. Ferdinands, and Peter J. Sinclair

This study aimed to investigate the bowling techniques of female fast bowlers and identify any association between a history of low back pain (LBP) and the movement patterns of the thorax relative to the pelvis during the delivery stride of the bowling action. Three-dimensional kinematic data were collected from 26 elite Australian female fast bowlers using an eight-camera Vicon motion analysis system. Nineteen bowlers used a mixed action, 6 bowlers used a semiopen action, and 1 bowler used a side-on action. Fourteen bowlers had a history of LBP. Eight of these 14 bowlers used a mixed action, and bowlers with more shoulder counterrotation were no more likely to have a history of LBP. Bowlers with a history of LBP positioned the thorax in more left lateral flexion relative to the pelvis between 73–79% of the delivery stride, and moved the thorax through a significantly greater range of lateral flexion relative to the pelvis during the delivery stride compared with bowlers with no history of LBP. This information will give coaches and support staff a better understanding of female bowling technique and may facilitate better screening practices for elite female cricketers.

Keywords: women’s cricket, fast bowling, technique, low back pain

Fast bowling technique in men’s cricket has received considerable attention from biomechanics researchers because movement patterns of the trunk during the delivery stride of the bowling action are considered to play an important role in the development of lower back injuries (Elliott, 2000), which are prevalent in male fast bowlers (Orchard et al., 2006).

Based on the alignment of the pelvis and shoulders in the transverse plane at back foot contact and the amount of counterrotation of the shoulder alignment in the transverse plane during the delivery stride, fast bowling technique can be broadly categorized into one of four action types: front-on, side-on, semiopen, and mixed (Portus et al., 2004). Higher shoulder counterrotation values are a key feature of the mixed bowling action and have consistently been associated with lower back injuries in both junior- (Foster et al., 1989; Elliott et al., 1992; Burnett et al., 1996) and senior- (Portus et al., 2004) level male fast bowlers.

The precise effect of shoulder counterrotation on lumbar spine mechanics has not been established (Elliott, 2000). Burnett et al. (1998) reported that bowlers using a mixed action tended to place the lumbar spine in more hyperextension and lateral flexion at front foot contact, and to move the lumbar spine through a greater range of lateral flexion during the delivery stride compared with bowlers using either a side-on or front-on action. However, a recent three-dimensional kinematic study of elite male fast bowlers found no correlation between shoulder counterrotation and the proportion of available lower trunk extension or lateral flexion that was used during the delivery stride of the bowling action (Ranson et al., 2008).

Irrespective of technique classification, lateral flexion may be an important consideration in the development of back injuries. In a prospective study of 24 senior Australian male fast bowlers, Portus et al. (2007) reported that bowlers with back injuries displayed greater ranges of lateral flexion of the lumbar spine between back foot contact and front foot contact, as well as a more laterally flexed lumbar spine at the instant of front foot contact. This is a concern because, of all trunk movements, elite male fast bowlers used the greatest proportion of available lower trunk range of motion in lateral flexion to the non-bowling-arm side (Ranson et al., 2008).

A recent investigation of the 26 elite Australian female fast bowlers in the current study reported that 14 (54%) had a history of low back pain (LBP) (Stuelcken et al., 2008). Of these 14 bowlers, 9 had experienced at least one episode of LBP in the previous 12 months and 6 reported recurrent episodes of LBP over their careers. The relationship between bowling technique and LBP in female fast bowlers is unclear because little is known about female fast bowling technique. The only published study to date was presented as a conference abstract and reported data on a limited selection of variables in a small sample of five bowlers (Savage & Portus, 2002). Therefore, the aims of this study were to (1) analyze the movement patterns of the thorax and pelvis of elite Australian female fast bowlers and classify the techniques of
these bowlers according to criteria previously established for male fast bowlers, and (2) determine whether there is an association between a history of LBP and the movement patterns of the thorax relative to the pelvis during the delivery stride of the bowling action. This information will give coaches and support staff a better understanding of female bowling technique and may facilitate better screening practices for elite female cricketers.

Methods

Twenty-six elite female fast bowlers (mean age, 22.5 ± 4.5 years; height, 170.6 ± 5.0 cm; mass, 66.2 ± 7.5 kg) participated in the study and each provided written consent before commencement. Bowlers were assessed during the first month of the competitive season using a protocol that was approved by the Human Research Ethics Committee at the University of Sydney.

Data Collection

Data pertaining to the bowlers’ history of LBP were gathered using a self-administered questionnaire as previously described in Stuelcken et al. (2008). A bowler was considered to have a history of LBP if self-reported pain (1) was attributable to or aggravated by performing cricket-related skills, (2) had occurred in the previous 12 months, or (3) had occurred at any stage in the bowler’s career and could be verified by records kept by team medical support staff. Episodes of self-reported LBP that did not meet these criteria were disregarded to minimize recall bias. This was considered to be quite a stringent definition for a retrospective study design and certainly consistent with those used in the scientific literature. Nevertheless, as the sample represented a “survivor” population, the true extent of the problem of LBP may have been underreported.

Forty-eight retro-reflective markers were attached to each bowler using double-sided adhesive tape. The markers on the acromion processes were 25 mm in diameter and all the remaining markers were 14 mm in diameter. The Plug-in-Gait marker set, which has been used in a previous study of male fast bowling technique (Salter et al., 2007), formed the basis of the marker set that was used in the current study. Additional markers were placed on the anterior and posterior aspects of each shoulder such that a line between the two markers represented the shoulder abduction/adduction axis of rotation (Roca et al., 2006). A triad of three markers mounted on a lightweight T-shaped frame was also placed on each upper arm segment such that two markers ran parallel with the long axis of the humerus, while the third marker was oriented medially (Roca et al., 2006). Reflective tape was placed on each side of the ball to determine when ball release occurred.

Three-dimensional data were collected using a Vicon 370 motion analysis system (Oxford Metrics Ltd., Oxford, United Kingdom). Eight infrared-sensitive cameras (12.5 mm lens, NAC Inc., Japan) operating at 120 Hz were positioned around a capture volume that was 4 m (long) × 1.5 m (wide) × 3 m (high). This permitted the full delivery action and initial ball flight to be captured. The global orthogonal coordinate system followed the right-hand rule with the positive x-direction oriented forward, the positive y-direction oriented to the left, and the positive z-direction oriented vertically upward. Calibration of all eight cameras was completed before each session of data collection. Across all testing sessions, the mean residual for each of the cameras was < 1.1 mm and the mean static reproducibility was < 1%.

After retro-reflective markers were attached, a static trial was obtained with each bowler standing in a wide-arm anatomical position. Each bowler then performed her own warm-up as for a match and bowled as many deliveries as required to become familiar with the testing environment. The laboratory allowed bowlers to use their normal length run-up and bowl at a set of stumps that were positioned at the end of a synthetic pitch surface. When ready, each bowler performed 20–25 maximum-effort deliveries with a standard women’s Kookaburra ball (mass, 0.140–0.151 kg). The accuracy of each delivery was determined using a marked target that was positioned on the batting crease (Portus et al., 2000).

Data Reduction

From each bowler, the four trials that had the smallest number of occluded markers and scored highly on the accuracy target by landing on a good line and length were selected for analysis. Data were filtered using Vicon’s built-in Woltring predicted mean square error quintic spline. A detailed residual analysis procedure (Winter, 2005) indicated a mean squared error of 25 was appropriate for these data. The shoulder, thorax, and pelvis segments were represented by a model developed by Portus (2006) using Bodybuilder for Biomechanics software (Oxford Metrics Group, UK). Each segment had an embedded orthogonal coordinate system based on standards set by the International Society of Biomechanics (Wu & Cavanagh, 1995). The model produced three-dimensional data for each segment in the global coordinate axis system and data for the relative angles between segments. Relative angles were calculated in a Z-X-Y decomposition sequence (Z = axial rotation, X = flexion-extension, Y = lateral flexion) and a relative angle of 0° represented a situation in which the axes were aligned in parallel. For the static standing trials, the angle of the thorax relative to the pelvis averaged 3.4° ± 7.2 extension, 1.0° ± 2.7 left axial rotation, and 1.5° ± 2.3 right lateral flexion.

The shoulder joint center was located at the intersection between a line connecting the anterior and posterior markers and a perpendicular line dropped from the marker on the acromion process (Roca et al., 2006). In the static trial, the shoulder joint center was recorded relative to the technical coordinate system of the triad of markers on the upper arm. This information was retrieved during bowling trials and used in the creation of a single
shoulder segment that was formed by a vector directed from shoulder joint center to shoulder joint center.

The thorax segment was represented by markers placed on the inferior aspect of the suprasternal notch, the superior aspect of the xiphoid process, the seventh cervical vertebra, and the tenth thoracic vertebra. The origin of the thorax coordinate system was located at the midpoint between the seventh cervical and tenth thoracic vertebrae (Mid-Thoracic). An additional virtual point was created at the midpoint between the inferior aspect of the suprasternal notch and the superior aspect of the xiphoid process (Mid-Sternum) to assist in the construction of the thorax coordinate system. The first defining line (x-axis) was a vector running from Mid-Thoracic to Mid-Sternum. The second defining line was a vector running from the seventh cervical to tenth thoracic vertebrae, and the mediolateral z-axis was the cross-product of this vector and the posterior-anterior x-axis. The cross-product of the z-axis and the x-axis produced the y-axis.

The pelvis segment was represented by markers placed on the anterior and posterior superior iliac spines. The origin of the pelvis coordinate system was located at the midpoint between the left and right anterior superior iliac spines. The first defining line (z-axis) was a vector running parallel to a line joining the markers on the anterior superior iliac spines and directed from the bowler’s left to right. The second defining line was directed from the origin of the pelvis to the midpoint between the markers on the posterior superior iliac spines, and the y-axis was the cross-product of this vector and the z-axis. The cross-product of the y-axis and the z-axis produced the anteriorly directed x-axis.

Marker trajectory data were used to determine key instances in the bowling action. The following definitions were used: back foot contact was the first frame when the foot was in full and flat contact with the ground. If full and flat contact did not occur, it was the frame when the heel was at its lowest point in relation to the ground. Front foot contact was the first frame when the foot was in full and flat contact with the ground. Ball release was the first frame when the ball was not in contact with the hand. Kinematic data for each trial during the delivery stride, defined as the period from back foot contact to ball release (0–100%), was time normalized to 101 data points using a cubic spline function within MATLAB (MathWorks, Natick, MA).

Two variables were used for the classification of bowling technique: pelvis-shoulder separation was the relative angle between the alignments of the pelvis and shoulder segments in the transverse plane at back foot contact. Shoulder counterrotation was calculated by subtracting the minimum alignment of the shoulder segment in the transverse plane between back foot contact and front foot contact from the alignment of the shoulder segment in the transverse plane at back foot contact. These angles are defined in Figure 1. A bowler was considered to have a mixed action if pelvis-shoulder separation was ≥ 30° at back foot contact or shoulder counterrotation was ≥ 30° (Portus et al., 2004). If both pelvis-shoulder separation at back foot contact and shoulder counterrotation were < 30°, the global rotation angle of the shoulder segment at back foot contact was used to classify bowling actions as either side-on (global rotation angle < 210°), semiopen (global rotation angle from 210° to 240°), or front-on (global rotation angle > 240°) (Portus et al., 2004). All data for left-handed bowlers were converted to read as data for right-handed bowlers.

**Statistical Analysis**

Preliminary examinations of discrete data were undertaken using the Shapiro–Wilks statistic and Fisher’s

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**Figure 1** — Schematic showing the definition of the orientation of the shoulder segment in the transverse plane with reference to the global coordinate axis system.
measures of skewness and kurtosis. As there were no violations in the assumption of normality, parametric statistical tests were selected for subsequent analyses. A number of subgroups were created and compared over selected variables. Data for bowlers using a semiopen or side-on action were pooled (Ranson et al., 2008) (“not-mixed” subgroup) and compared with bowlers using a mixed action (“mixed” subgroup) and data for bowlers with a history of LBP (“LBP” subgroup) were compared with bowlers with no history of LBP (“No LBP” subgroup). The LBP and No LBP subgroups were established using the data in Stuelcken et al. (2008). Between-group comparisons were made using the independent samples t test. To support these tests, effect sizes were calculated and evaluated using the scale of Hopkins (1997), where an effect size of 0.2–0.6 was considered to be a small effect; an effect size of 0.6–1.2, a moderate effect; and an effect size of 1.2–2.0, a large effect. The Pearson product–moment correlation coefficient was used to determine the association between the alignment of the shoulders at back foot contact and shoulder counterrotation. A correlation coefficient of 0.3–0.5 was considered to be a moderate association; a coefficient of 0.5–0.7, a large association; and a coefficient of 0.7–0.9, a very large association (Hopkins, 1997). Differences between group mean waveforms ± 95% confidence limits were calculated and plotted over the delivery stride. When calculating the confidence limits, the critical value of t was obtained with the number of degrees of freedom associated with the unpaired t test adjusted so as to not assume homogeneity of variance. For all statistical tests, the significance level was set at p < .05. Statistical analyses were undertaken using SPSS for Windows (version 14.0).

Results

In this sample of 26 elite female fast bowlers, 19 (73%) bowlers used a mixed action, 6 (23%) bowlers used a semiopen action, and 1 (4%) bowler used a side-on action. Of the 19 bowlers who used a mixed action, 1 bowler was classified as mixed based solely on the pelvis-shoulder separation angle at back foot contact, 12 bowlers were classified as mixed based solely on the amount of shoulder counterrotation, and 6 bowlers were classified as mixed based on both the pelvis-shoulder separation angle at back foot contact and the amount of shoulder counterrotation.

The mean pelvis-shoulder separation angles at back foot contact were 24.5° ± 12.0 and 14.0° ± 9.0 for the mixed and not-mixed subgroups respectively, and the mean shoulder counterrotation angles were 46.0° ± 12.8 and 21.5° ± 5.7 for the mixed and not-mixed subgroups respectively. There was a very large correlation (r = .824, p = .00) between the alignment of the shoulders at back foot contact and the magnitude of subsequent shoulder counterrotation. When comparing the mixed and not-mixed subgroups, there was no significant difference in the alignment of the thorax relative to the pelvis at front foot contact (p > .05), nor were there any significant differences in the maximum range of flexion-extension or lateral flexion of the thorax relative to the pelvis during the delivery stride (p > .05). Based on the definition used in this study, 14 (54%) of the bowlers had a history of LBP. Eight (57%) of these 14 bowlers used a mixed action but bowlers with more shoulder counterrotation were no more likely to have a history of LBP (Table 1).

Group mean waveforms for the alignment of the thorax relative to pelvis during the delivery stride for bowlers with and without a history of LBP are displayed in Figure 2, and differences between group mean waveforms ± 95% confidence limits are displayed in Figure 3. The thorax of the LBP subgroup was more laterally flexed to the left relative to the pelvis between 73–79% of the delivery stride compared with the No LBP subgroup (Figure 2c). This finding is illustrated in Figure 3c, where both the upper and lower 95% confidence limits surrounding the difference between the group means were less than zero.

The mean maximum angles of the thorax relative to the pelvis during the delivery stride for bowlers with and without a history of LBP are displayed in Table 2. The mean maximum lateral flexion range of the thorax relative to the pelvis during the delivery stride was significantly greater for the LBP subgroup compared with the No LBP subgroup (p = .004). This was a large effect size (g = 1.25). There were no other differences between the LBP and No LBP subgroups.

Table 1 The percentage of bowlers within each 10° range of shoulder segment counterrotation with a history of low back pain

<table>
<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Number of bowlers</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Bowlers with a history of LBP</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Percentage</td>
<td>100</td>
<td>83</td>
<td>50</td>
<td>50</td>
<td>25</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 2 — Group mean waveforms for the alignment of the thorax relative to pelvis during the delivery stride (BFC-BR) for female fast bowlers with a history of low back pain (LBP) compared with female fast bowlers with no history of low back pain (No LBP); BFC = back foot contact, BR = ball release.
Figure 3 — Differences in the alignment of the thorax relative to pelvis during the delivery stride (BFC-BR) between female fast bowlers with a history of low back pain (LBP) and female fast bowlers with no history of low back pain (No LBP). The differences between group means (solid line) ± 95% confidence limits (shaded region) are plotted over the delivery stride; BFC = back foot contact, BR = ball release.
A standardized classification system for male fast bowling technique has yet to be established, so different measures and threshold criteria have been applied by different research groups. This has made comparisons between studies difficult. The current study adopted a classification system presently used by Cricket Australia in the assessment of elite male fast bowlers and found that 19 of 26 (73%) elite female fast bowlers in this sample used a mixed action. Although the use of a “back foot flat” rather than a “back foot impact” definition may have reduced the number of bowlers that were classified as mixed (Ranson et al., 2008), elite female fast bowlers would appear to be just as likely to use a mixed action as their male counterparts. Consistent with a recent finding in professional male fast bowlers (Ranson et al., 2008), none of the female fast bowlers used a front-on action. Bowlers who attempted to use a front-on alignment of the shoulders at back foot contact were rarely able to maintain this position and proceeded to counterrotate the shoulders to a more side-on alignment during the early stages of the delivery stride. This tendency has also been observed in male fast bowlers (Portus et al., 2004; Ranson et al., 2008).

Shoulder counterrotation has consistently been associated with lower back injuries in both elite junior- (Foster et al., 1989; Elliott et al., 1992) and senior- (Portus et al., 2004) level male fast bowlers. In the current study, however, elite female fast bowlers with high shoulder counterrotation were no more likely to have a history of LBP. There may be a number of reasons for this finding. Firstly, as an isolated kinematic parameter, shoulder counterrotation is not a measure of lumbar torsional load (Elliott, 2000). It may, therefore, be inadequate to view the rotation of the shoulders in isolation because a corresponding movement pattern at the pelvis may reduce the risk of lower back damage (Stockill & Bartlett, 1992). Hence, the relationship between the axial rotation of the thorax and pelvis during the delivery stride was investigated. It is evident from Figure 4 that female bowlers classified as mixed displayed little change in the alignment of the pelvis during the first 40% of the delivery stride, whereas female bowlers classified as not mixed commenced the left rotation of the pelvis within the first 10% of the delivery stride. This delay in the initiation of the left rotation of the pelvis for bowlers using a mixed action may have reduced the intersegment separation angle and alleviated, to some extent, the load imposed on the lumbar spine by the counterrotation of the thorax.

Secondly, it has been suggested that shoulder counterrotation may increase the potential for injury because it places the lumbar spine in a more hyperextended and laterally flexed position at front foot contact (Burnett et al., 1998). However, the mixed subgroup did not exhibit any difference in the alignment of the thorax relative to the pelvis at front foot contact, or any differences in the maximum angular range of flexion-extension or lateral flexion of the thorax relative to the pelvis during the delivery stride compared with the not-mixed subgroup. This finding is consistent with the work of Ranson et al. (2008), who used a lower thorax reference frame and reported no correlation between shoulder counterrotation and the proportion of available lower trunk extension or lateral flexion of the thorax relative to the pelvis during the delivery stride compared with the not-mixed subgroup.

Thirdly, the link between the mixed bowling action and injury to the lumbar spine has often been based on radiological evidence of the presence of bony abnormalities of the partes interarticularae. Diagnostic imaging was not available in this study, so we are unable to comment on the structural status of the lumbar spines of the female

**Table 2** Mean maximum angles of the thorax segment in relation to the pelvis segment during the delivery stride for female fast bowlers with and without a history of low back pain

<table>
<thead>
<tr>
<th>Variable</th>
<th>LBP Subgroupa (n = 14)</th>
<th>No LBP Subgroupb (n = 12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum left axial rotation</td>
<td>9.9 (6.6)</td>
<td>15.1 (10.0)</td>
</tr>
<tr>
<td>Maximum right axial rotation</td>
<td>–25.6 (6.1)</td>
<td>–26.8 (5.6)</td>
</tr>
<tr>
<td>Range</td>
<td>35.5 (9.3)</td>
<td>41.8 (13.1)</td>
</tr>
<tr>
<td>Maximum flexion</td>
<td>27.2 (12.1)</td>
<td>29.4 (10.5)</td>
</tr>
<tr>
<td>Maximum extension</td>
<td>–14.2 (9.1)</td>
<td>–12.5 (8.6)</td>
</tr>
<tr>
<td>Range</td>
<td>41.4 (7.9)</td>
<td>41.9 (9.3)</td>
</tr>
<tr>
<td>Maximum left lateral flexion</td>
<td>–41.9 (5.8)</td>
<td>–38.4 (6.3)</td>
</tr>
<tr>
<td>Maximum right lateral flexion</td>
<td>6.7 (6.4)</td>
<td>3.6 (7.1)</td>
</tr>
<tr>
<td>Range</td>
<td>48.6 (5.7)*</td>
<td>42.0 (4.7)</td>
</tr>
</tbody>
</table>

*Note.* Values are mean (SD). Angle is expressed in degrees.

aLBP subgroup = Bowlers with a history of low back pain at the commencement of the study.
bNo LBP subgroup = Bowlers with no history of low back pain at the commencement of the study.

*Significantly different to the No LBP subgroup, p < .05.

**Discussion**

A standardized classification system for male fast bowling technique has yet to be established, so different measures and threshold criteria have been applied by different research groups. This has made comparisons between studies difficult. The current study adopted a classification system presently used by Cricket Australia in the assessment of elite male fast bowlers and found that 19 of 26 (73%) elite female fast bowlers in this sample used a mixed action. Although the use of a “back foot flat” rather than a “back foot impact” definition may have reduced the number of bowlers that were classified as mixed (Ranson et al., 2008), elite female fast bowlers would appear to be just as likely to use a mixed action as their male counterparts. Consistent with a recent finding in professional male fast bowlers (Ranson et al., 2008), none of the female fast bowlers used a front-on action. Bowlers who attempted to use a front-on alignment of the shoulders at back foot contact were rarely able to maintain this position and proceeded to counterrotate the shoulders to a more side-on alignment during the early stages of the delivery stride. This tendency has also been observed in male fast bowlers (Portus et al., 2004; Ranson et al., 2008).

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Thirdly, the link between the mixed bowling action and injury to the lumbar spine has often been based on radiological evidence of the presence of bony abnormalities of the partes interarticularae. Diagnostic imaging was not available in this study, so we are unable to comment on the structural status of the lumbar spines of the female
fast bowlers. Therefore, we have referred to “pain” in preference to “injury.” The relationship between pain, function, and the findings from scans remains unclear because, just as a scan may not provide an indication of the underlying cause of LBP (Refshauge & Maher, 2006), it is also possible that the presence of bony or intervertebral disc abnormalities in the lumbar spines of fast bowlers may not always be accompanied by pain (Ranson et al., 2005). These differences in the criteria for classifying “injury” need to be considered when interpreting the findings presented in this study. Finally, the current study used a retrospective design and bowlers may have changed their bowling technique due to previous LBP (Portus et al., 2004). These changes may have resulted from either a coaching intervention or protective strategies adopted by the bowler to prevent the recurrence of pain.

Lateral flexion would appear to be an important technique consideration for elite female fast bowlers. The LBP subgroup demonstrated more left lateral flexion of the thorax relative to the pelvis between 73–79% of the delivery stride compared with the No LBP subgroup. This represents the initial period between front foot contact and ball release when lateral flexion is strongly coupled with right axial rotation (Figure 2b). Studies have reported that intervertebral disc strain increases greatly with lateral loading and with increases in combined plane loading (Shirazi-Adl, 1991; Shirazi-Adl et al., 1986), and the tolerance of the disc may be further challenged by the high velocity at which lateral flexion is occurring at this time (Marras & Granata, 1997). The mean maximum lateral flexion range of the thorax relative to the pelvis during the delivery stride was also significantly greater for the LBP subgroup compared with the No

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**Figure 4** — Axial rotation of the thorax and pelvis segments during the delivery stride (BFC-BR) for female fast bowlers classified as “mixed” [a] and “not mixed” [b]; BFC = back foot contact, BR = ball release.
LBP subgroup. The zygapophyseal joints and capsular ligaments afford resistance to lateral bending, but a large movement range may produce high stress concentrations within the cartilage surface of the zygapophyseal joints (Adams et al., 2006) and elicit pain (Cavanaugh et al., 1996). In similar findings to the current study, Portus et al. (2007) reported that back-injured senior-level male fast bowlers displayed greater ranges of lateral flexion of the lumbar spine between back foot contact and front foot contact, as well as a more laterally flexed lumbar spine at the instant of front foot contact. It has also been suggested that a large lateral flexion angle in the bowling action may cause significant stress to the lumbar parties interarticularae of male fast bowlers (Ranson et al., 2008).

Although the importance of lateral flexion in the etiology of lower back injuries in elite female fast bowlers requires further investigation, the findings of the current study may have implications for technique remediation. Historically, coaches have focused on correcting movement patterns of the trunk in the transverse plane between back and front foot contact in the delivery stride of the bowling action (Elliott & Khangure, 2002; Wallis et al., 2002). However, perhaps more attention needs to be given to reducing excessive lower trunk motion, particularly lateral flexion, which typically peaks after front foot contact (Ranson et al., 2008). A simple method of identifying bowlers at risk for injury through excessive lower trunk lateral flexion using two-dimensional video data may prove to be a useful tool for coaches, and work is being done to determine the accuracy of such measurements compared with three-dimensional data (Worthington et al., 2007).

The current study had a number of limitations. Firstly, only trunk kinematics were investigated so future prospective studies quantifying kinetic loads will be required to establish causal links between the bowling action and LBP. Secondly, information on the underlying causes of low back pain in these female fast bowlers was not available. Based on player recall and records kept by team medical support staff, no bowler in this sample missed more than 4 weeks of training or match play with each episode of LBP. As spondylolysis and other serious conditions of the lumbar spine in male fast bowlers often necessitate an extended absence from cricket participation (Orchard et al., 2006), this finding may indicate differences in the type of lower back injuries sustained by female and male fast bowlers. Further work is required to clarify this issue. Finally, the sample size was relatively small. However, the sample represented all but one of the female fast bowlers who were identified as elite by the Australian women’s cricket coach at the time of testing. If larger sample sizes of elite female fast bowlers are required, then future studies will need to recruit bowlers from other cricket-playing nations.

In conclusion, elite female fast bowlers were just as likely to use a mixed action as their male counterparts and bowlers with a mixed action were no more likely to have a history of LBP. Lateral flexion of the thorax relative to the pelvis was the key variable that distinguished between bowlers with and without a history of LBP.

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References


