The Shoulder Distraction Force in Cricket Fast Bowling

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

This preliminary study aimed to quantify the magnitude of the peak shoulder distraction force during the bowling action of female cricket fast bowlers. An eight camera Vicon motion analysis system operating at 120 Hz recorded the fast bowling actions of 18 Australian female fast bowlers. A three segment inverse solution model of the bowling arm was used to calculate the shoulder distraction force. A large peak shoulder distraction force was recorded during the early stages of the follow-through of the bowling action. When normalized for body weight, the distraction force was within the range of values reported for baseball and softball pitchers, who are considered to be at high risk of shoulder injury. Therefore, the relative importance of the peak shoulder distraction force in the fast bowling action for the development of shoulder pain in female cricket fast bowlers warrants further investigation.

Keywords: women’s cricket, fast bowling, shoulder, kinetics

Studies have identified the peak shoulder distraction force as an important consideration in the development of shoulder injuries in baseball and softball pitchers (Barrentine et al., 1998; Werner et al., 2001). This is because considerable muscular support is required to dynamically stabilize the shoulder joint against distraction during the performance of these skills (Blevins, 1997). A history of shoulder pain is also a common problem in female cricket fast bowlers (Stuelcken et al., 2008) and anecdotal evidence based on clinical files indicates that this pain may be attributable to rotator cuff and long head of biceps brachii injuries.

Fast bowlers are required to both bowl and throw and it has been suggested that shoulder injuries tend to result from throwing rather than bowling (Myers & O’Brien, 2001). This may be because unlike throwing, the bowling action does not have a cocking phase. Therefore, the bowling arm does not get positioned in abduction and forced external rotation and the capsular ligaments are not subjected to forces that may lead to anterior instability (Myers & O’Brien, 2001). The bowling shoulder, however, may be vulnerable to distraction forces. A high circumduction velocity of the bowling arm is important for the generation of fast ball release speeds in male fast bowling (Salter et al., 2007). Furthermore, due to strict laws relating to the amount of elbow extension that can occur from when the bowling arm is parallel to the ground and behind the bowler through to ball release, much of the circumduction motion of the bowling arm is performed with the elbow close to full extension. The combined effect of these two factors will necessitate a greater centripetal force to prevent distraction at the shoulder joint.

The aim of this preliminary study is to quantify the magnitude of the peak shoulder distraction force in the fast bowling action. The number of balls bowled by a fast bowler is likely to greatly exceed the number thrown by that player. Therefore, if the bowling action does produce a high shoulder distraction force, this could be a potential mechanism in the development of shoulder pain in female cricket fast bowlers that would warrant further investigation in the future.

Methods

Eighteen female fast bowlers (mean age 23.8 ± 4.7 years, height 169.5 ± 5.4 cm, mass 67.0 ± 7.4 kg) who were identified as elite by the Australian women’s cricket coach consented to participate in the study. Thirteen bowlers were right-handed and five were left-handed and all 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.

Three-dimensional video data were collected using an eight camera VICON 370 motion analysis system (Oxford Metrics Ltd., Oxford, UK). 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). 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%.
Thirty-four retro-reflective markers were attached to anatomical landmarks on each bowler according to the Plug-in-Gait model (Oxford Metrics Ltd., Oxford, UK). This model has been used in previous analyses of the arm in overhead sporting skills (Sachlikidis and Salter, 2007; Trewartha et al., 2008). Reflective tape was also placed on the ball, which was a standard women’s Kookaburra cricket ball. After retro-reflective markers were attached, a static trial was obtained with each bowler standing in an anatomical position with arms abducted. Bowlers then performed their 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 positioned at the end of a synthetic pitch surface.

Due to the positioning of the head and upper limbs in relation to the trunk at various stages of the bowling action it was often difficult to obtain complete trials where no markers were occluded by body segments. This study was embedded within a larger investigation of fast bowling technique that required the full bowling action to be captured. Therefore, 20–25 maximum-effort deliveries were collected for each bowler. The marker data for between one and three deliveries for each bowler in the current study were considered to be of sufficient quality to warrant modeling. Data were filtered using a zero phase lag fourth-order Butterworth filter. A cut-off frequency of 12 Hz was selected after a detailed residual analysis (Winter, 2005) and visual inspection of the acceleration curves.

A local coordinate axis system was established at the shoulder. The positive y-direction was directed along the long axis of the upper arm segment, the positive z-direction was the cross product of the y-axis and a line connecting the lateral humeral epicondyle and elbow joint center, and the positive x-direction was the cross product of the y and z-axes. Angular kinematics were calculated with respect to an orthogonal joint coordinate system at the bowling arm that was based on the definition of general Euler angles (Ferdinands, 2004; Grood & Suntay, 1983). A Z-Y-X Euler angle decomposition sequence was used to define the orientation of the joint coordinate system of the bowling arm with respect to the global coordinate system. The resultant force at the shoulder joint was then calculated using a three segment inverse solution model of the bowling arm (Ferdinands, 2004) that was developed using the Mechanical Systems Package within Mathematica 5.2 (Wolfram Research Inc.). The software is designed for the analysis of spatial rigid body mechanisms, and uses an iterative Newton-Lagrange multiplier method to generate the dynamic equations of motion (Haug, 1989). Segment masses and moments of inertia were determined using the equations of De Leva (1996). The ball was added to the model by constraining the distance of the center of mass of the ball from the center of mass of the hand. In effect, the mass of the ball was added to the mass of the hand. The ball was removed from the model at release, which was defined as the first video image when the ball was not in contact with the hand. The resultant force at the shoulder joint was transformed into the local coordinate axis system and the compressive-distractive component was determined. Forces were expressed in absolute units and normalized for body weight. The angle of the bowling arm was projected onto the sagittal plane and defined as indicated in Figure 1. Data were investigated within the 180° arc of the bowling arm depicted in Figure 2.

Preliminary investigations of the data for the eleven bowlers with at least two available trials revealed there was little difference (0.002%) in the mean peak shoulder distraction force for this subset of bowlers irrespective of whether one or two trials were used for each bowler. Given the descriptive nature of this preliminary study, it was therefore decided that a representative value for the population of female fast bowlers would be provided by including data for one trial for all 18 bowlers. For bowlers with more than one available delivery, the trial with the highest ball speed at release was used. It is acknowledged that the use of one trial for each bowler, rather than the average of multiple trials, may be a limitation of the current study.

**Results**

The peak shoulder distraction force for the female fast bowlers is presented in Table 1. The peak shoulder distraction force of 599 N ± 111 occurred at a mean bowling arm angle of 27° ± 15 past the vertical. As the mean bowling arm angle at ball release was 15° ± 5 past the vertical, the shoulder distraction force generally peaked during the early stages of the follow-through. The mean ball speed at release was 26 m s⁻¹ ± 1. Shoulder distraction force curves for two bowlers with ball release speeds at the low and high end of the recorded range are displayed in Figure 3.

**Figure 1** — Definition of the bowling arm angle.
Shoulder Distraction Force in Cricket

Figure 2 — The 180° arc of the bowling arm in which data were investigated.

Discussion

A large distraction force was recorded at the shoulder joint during the early stages of the follow-through of the bowling action. When normalized for body weight, the average peak distraction force (0.92) was similar to values reported for male baseball pitchers (1.08) (Werner et al., 2001), female baseball pitchers (0.73) (Chu et al., 2009), and female softball pitchers (0.80) (Werner et al., 2006). Due to the limitations of inverse dynamics analyses the potential relationship between joint forces and injury can only be discussed in theory (Fleisig et al., 1999). However, if the shoulder distraction force is considered to play an important role in the development of shoulder injuries in baseball and softball pitchers (Barrentine et al., 1998; Werner et al., 2001), then the shoulder distraction
The peak shoulder distraction force in the bowling action should also be considered as a contributing factor in the development of shoulder pain in female fast bowlers.

The main mechanism to resist the distraction force at the shoulder joint is provided by the muscles of the rotator cuff which dynamically stabilize the joint by creating a compressive force that centers the humeral head within the glenoid cavity (Blevins, 1997). Active tension within the long head of biceps tendon may also assist in providing a compressive force at the shoulder (Fleisig et al., 1995) because the biceps brachii is likely to be contracting throughout the circumduction motion of the bowling arm to control elbow extension. The repetition of the large distraction forces recorded in this study may be sufficient to cause overload of the rotator cuff (Belling Sørensen & Jørgensen, 2000). This may be especially the case if the rotator cuff is weakened or fatigued. Previous research has indicated that the ratio of eccentric external to concentric internal rotation strength in the bowling shoulder of elite female fast bowlers is well below a level considered necessary for appropriate muscle balance to maintain adequate dynamic stability at the shoulder joint (Stuelcken et al., 2008). A sudden increase in training workload or frequency of matches may further stress the muscles of the rotator cuff beyond their ability to adapt and repair (Blevins, 1997) and this may explain why support staff often treat more cases of shoulder pain in members of the Australian women’s cricket squad during an overseas tour (Ross, 2000). Dysfunction of the rotator cuff or capsular ligaments could increase the role of biceps brachii in providing dynamic shoulder stability (Pagnani et al., 1996) and may render the biceps labrum complex susceptible to overuse injury (Barrentine et al., 1998).

It has been suggested that shoulder injuries in bowlers tend to result from throwing rather than bowling (Myers & O’Brien, 2001). The current study, however, indicates that the peak shoulder distraction force in the fast bowling action was of similar magnitude to recorded values in baseball and softball pitching. Given that the number of balls bowled by a fast bowler is likely to greatly exceed the number thrown by that player, this suggests that the forces in the bowling action are likely to be large enough to contribute to the development of shoulder pain due to rotator cuff and long head of biceps brachii injuries. To gain a better understanding of injury mechanisms, musculoskeletal modeling of the shoulder complex needs to be undertaken so that forces within anatomical structures can be assessed.

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**References**


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fast Bowling</th>
<th>Softball Pitching&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Baseball Pitching&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak shoulder distraction force (N)</td>
<td>599 (111)</td>
<td>566 (190)</td>
<td>510 (108)</td>
</tr>
<tr>
<td>Range (N)</td>
<td>420–824</td>
<td></td>
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<td>Peak shoulder distraction force (BW)</td>
<td>0.92 (0.15)</td>
<td>0.80 (0.22)</td>
<td>0.73 (0.25)</td>
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<tr>
<td>Range (BW)</td>
<td>0.68–1.38</td>
<td>0.50–1.49</td>
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</tr>
<tr>
<td>Ball speed at release (m s&lt;sup&gt;-1&lt;/sup&gt;)</td>
<td>26 (1)</td>
<td>27 (2)</td>
<td>26.8 (2)</td>
</tr>
</tbody>
</table>

Note. N = newtons, BW = body weights.

<sup>a</sup>Data from Werner et al. (2006).

<sup>b</sup>Data from Chu et al. (2009).


