CAN FIELD-BASED TWO-DIMENSIONAL MEASURES BE USED TO ASSESS THREE-DIMENSIONAL LUMBAR INJURY RISK FACTORS IN CRICKET FAST BOWLERS?

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Bayne et al. (2016) recently established a direct link between lumbar injury incidence and increased 3D measures of thorax lateral flexion, pelvis rotation and hip extension during the cricket fast bowling action. However, the majority of bowlers are not able to avail themselves to 3D biomechanical analysis. Therefore, we set out to ascertain whether it is appropriate to use 2D measures to assess 3D lumbar injury risk factors in fast bowlers. Nineteen fast-medium bowlers were simultaneously recorded by 3D motion capture and 2D video. Results showed that 2D thorax lateral flexion and pelvis rotation at ball release correlate particularly well with the 3D equivalents. The information presented may be practically applied by coaches to improve field-based lumbar injury risk screening processes.

KEY WORDS: screening, low back injury, thorax lateral flexion

INTRODUCTION: Debilitating lumbar injuries such as spondylolysis and intervertebral disc degeneration are prevalent amongst adolescent and young adult cricket fast bowlers (Johnson, Ferreira, & Hush, 2012). It is widely accepted that bowling technique is a major aetiological factor of injuries to the lumbar region (Bayne, Elliott, Campbell, & Alderson, 2016; Elliott, 2000; Elliott, Hardcastle, Burnett, & Foster, 1992; Foster, John, Elliott, Ackland, & Fitch, 1989; Johnson et al., 2012). Bayne and colleagues (2016) recently reported that adolescent fast bowlers who suffered a lumbar injury over the course of a cricket season exhibited increased levels of thorax lateral flexion (TLF) at front foot contact (FFC) and ball release (BR), pelvis rotation at BR, and hip extension at FFC (Bayne et al., 2016). In the same study, higher peak lumbar flexion-extension and lateral flexion moments were also reported in bowlers who suffered a lumbar injury. Though the link is clearly significant, the kinematic and kinetic variables were identified using a three-dimensional (3D) motion capture system. Retro-reflective motion capture is the current gold standard method of motion analysis, however it is not readily available to most cricket coaches and players, except those at the elite level of the game. Therefore, this research aimed to bridge part of the gap between current biomechanical knowledge of lumbar injury risk and practical application of this research. We hypothesised that it would be possible to reliably replicate the measurement of the four key kinematic variables previously mentioned via two-dimensional (2D) multiple-plane video analysis. Video cameras are comparatively affordable and user friendly, potentially allowing coaches greater opportunity to assess bowling actions for increased risk of lumbar injury before such an injury occurs.

METHODS: Nineteen male fast-medium bowlers (16.6±3.3 years, 182.5±9.5 cm, 72.2±12.9 kg) from district or community level cricket clubs consented to having their bowling actions recorded in the sports biomechanics laboratory at the University of Western Australia. All participants bowled 12 deliveries at match level intensity at a set of wickets, with three 'good' length balls selected for analysis. A 22-camera Vicon motion analysis system (Vicon, Oxford Metrics, Oxford, UK) was used to record 3D trajectory data. A customised, retro-reflective marker set (14mm diameter) and model was applied to the lower limbs, trunk, bowling arm and lumbar spine of all participants (Crewe, Campbell, Elliott, & Alderson, 2013; Dempsey et al., 2007). Static calibration trials collected medial and lateral malleoli positions, with 6-marker pointer calibration trials used to place virtual markers on the lateral and medial epicondyles of the bowling arm and medial and lateral femoral condyles of both lower limbs using the calibrated anatomical systems technique (Cappozzo, Catani, Della Croce, & Leardini, 1995). Dynamic functional methods were used to determine joint axes of rotation for the bowling elbow and bilateral knee and hip joint centres (Besier, Sturnieks, Alderson, & Lloyd, 2003). A fourth-order, low-pass Butterworth filter (14Hz cut-off) was applied to the data, with cut-off determined via residual analysis (Winter, 1990).

Video footage was captured in the transverse and sagittal (bowling arm side) planes by two high-speed Vicon Bonita 2D video cameras (250Hz) synchronised to the 3D system. Two Sony Handycam HDR-CX700 50Hz video cameras (Sony Corporation, Tokyo, Japan) were positioned in a coronal plane behind the bowler's run up and in a sagittal plane on the non-bowling arm side. All camera shutter-speeds were set to the maximum possible speed (1/600th-1/1000th second) given the ambient light conditions to reduce blur. SiliconCoach Pro 7 (The Tarn Group, Dunedin, New Zealand) was used to calculate 2D angles from the video footage. TLF angle was measured from the coronal video (50Hz) at FFC and BR, using markers on C7 and L5. A 0° value indicated a perfectly upright trunk, with a positive value indicating the bowler was leaning towards the non-bowling arm side. Pelvis rotation was calculated at BR using the transverse video (250Hz) and the posterior superior iliac spine markers. A 0° angle indicated the pelvis was exactly parallel to the bowling crease (i.e. front-on position), with a positive value indicating rotation past a perfectly front-on position. Front-leg hip flexion-extension angle at FFC and front-leg knee flexion-extension angle at FFC and BR were calculated from the non-bowling arm side sagittal video (50Hz). The iliac crest, head of the femur, lateral condyle of the femur and the lateral malleoli were used for these angle measurements. BR height was calculated from the sagittal video on the bowling arm side (250Hz). Knee flexion-extension and BR height have been associated with lumbar injury previously (Foster et al., 1989; Portus, Mason, Elliott, Pfitzner, & Done, 2004). All 2D measurements were repeated three times, with the mean value used. Intra-rater reliability had been previously determined by a similar study (Weir, Smailes, Alderson, Elliott, & Donnelly, 2013). 2D kinematic variables are displayed in figure 1.

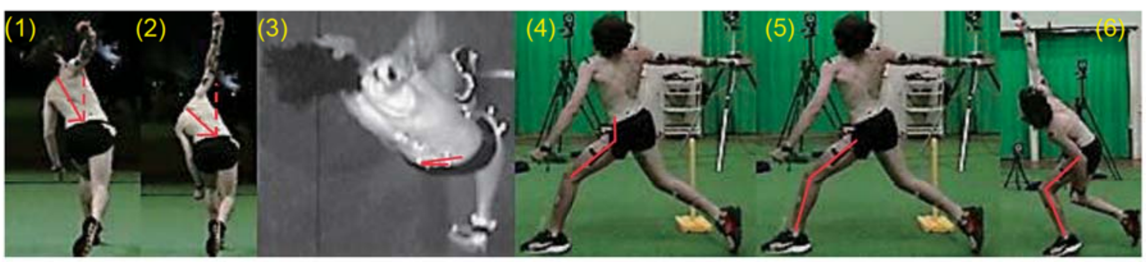

Figure 1: (1) TLF at FFC, (2) TLF at BR, (3) pelvis rotation at BR, (4) hip flexion-extension at FFC, (5) knee flexion-extension at FFC, and (6) knee flexion-extension at BR.

The front foot of each bowler landed on a 1.2m x 1.2m AMTI force plate (Advanced Mechanical Technology Inc., Watertown, MA) recording at 2000Hz, enabling the FFC event to be determined. BR was determined from the synchronized high speed video (Wells, Donnelly, Dols, Elliott, & Alderson, 2015). An intra-class correlation (ICC) with absolute agreement was used to compare the 2D and 3D kinematic values from 57 trials. Average measurement difference (°) between the two methods was also calculated for each variable. A one-tailed, bivariate Pearson correlation was used to investigate the association between 2D BR height (normalised to participant standing height) and 3D TLF angle at BR.

RESULTS AND DISCUSSION: Overall, the 2D measurements correlated strongly with the 3D kinematic measurements. The ICC coefficients with absolute agreement and mean 2D-3D measurement differences are displayed in table 1. 2D measurements of TLF at FFC (ICC=0.65) and BR (ICC=0.73) returned strong absolute agreement ICC with the 3D angles. However, 2D TLF at FFC was on average 5.9°±5.3° less than 3D TLF at FFC. In comparison, 2D TLF at BR was only 1.6°±5.5° less than the 3D values. We speculate that the greater difference at FFC is due to the bowlers' trunks being in a semi-rotated position at this point. This meant the measurement was taken slightly out of plane with the coronal plane camera.

In comparison, bowlers are in a relatively front-on position by the time they release the ball, making 2D measurement from a coronal camera fairly simple. The measurement error of 2D TLF at FFC may be partially rectified by placing an additional video camera behind the bowling crease at approximately 45°. However, the considerable variation in bowler trunk positions means this variable will be inherently more difficult to measure consistently than TLF at BR, regardless of camera position.

Table 1: 3D and 2D kinematic variable intra-class correlations with absolute agreement and mean measurement differences

Kinematic Variable	2D-3D ICC with absolute agreement	Mean measurement difference (degrees)
TLF at FFC	0.65*	5.9±5.3
TLF at BR	0.73*	1.6±5.5
Pelvis rotation at BR	0.91*	4.5±3.8
Front-leg hip flexion-extension at FFC	0.58*	0.4±8.3
Front-leg knee flexion-extension at FFC	0.38*	5.3±7.8
Front-leg knee flexion-extension at BR	0.97*	1.6±4.0

*Significant at $p<0.001$

A very strong correlation coefficient was found for pelvis rotation at ball release (ICC=0.91). There was a tendency for the 2D measurements (4.5°±3.8°) to be greater than the 3D, but a relatively low standard deviation suggests good measurement repeatability. This was the only one of the four key variables to be measured from the 250Hz video. A major benefit of the 250Hz video was that FFC and BR could be matched exactly with the 3D data. It is probable that some of the 2D to 3D measurement differences in the other variables can be contributed to measurements being observed at slightly different time points (i.e. not precisely at BR or FFC) due to the 50Hz frame rate.

Front-leg hip flexion-extension at FFC produced a comparatively weak ICC (0.58) when compared with the other key kinematic variables identified by Bayne and colleagues (2016). It also returned the largest standard deviation in measurement difference (0.4°±8.3°). Front-leg knee flexion was also measured at FFC and BR. Surprisingly, knee flexion at FFC produced only a moderate ICC of 0.38, whereas the same measurement at BR correlated extremely well with the 3D values (ICC=0.97). Average measurement difference was also much greater at FFC (5.3°±7.8°) than at BR (1.6°±4.0°). The comparatively weak correlations and large 2D to 3D measurement differences for both knee and hip flexion-extension at FFC may be due to the rapid knee flexion or extension that occurs just after a bowler's front foot makes contact with the ground. As these 2D measurements were taken from the 50Hz video, it is likely that the FFC frame differences between the 50Hz video and the 250Hz 3D data have significantly impacted the hip and knee angle measurements at FFC. The flexion-extension angular velocity at the knee slows considerably by BR, hence the much stronger correlation between the 3D and 2D measurements.

A strong Pearson correlation of -0.67 ($p=<0.001$) was found between 2D BR height and 3D TLF at BR. We suggest that coaches can utilise BR height as a secondary measurement of TLF at BR, when looking to identify bowlers at an increased risk of lumbar injury. A BR height less than 110% of standing height may suggest greater TLF. In this study, those bowlers (n=11) who averaged a BR height of less than 110% of their standing height had a mean 3D TLF angle at BR of 51.3°±6.8°. Significantly ($p=0.01$), those who had a BR height greater than 110% of standing height (n=8), had a TLF angle of 42.5°±6.1°. For TLF at BR, <50° is considered to be in the higher lumbar injury risk range (Bayne et al., 2016).

These findings suggest 2D video analysis is an appropriate method of lumbar injury risk measurement in fast bowlers. The following summary points may be useful to coaches, players and other cricket researchers:

1. 2D measurement of TLF is more repeatable at BR than at FFC.
2. 2D BR height <110% of standing height may also suggest increased levels of TLF.
3. An additional video camera placed behind the bowling crease at approximately 45° may facilitate a more accurate measurement of TLF at FFC than a coronal camera.
4. 2D pelvis rotation can be accurately measured from a transversely positioned camera.
5. Front-leg hip and knee flexion-extension 2D angle measurement may be impacted by the rapid flexion or extension at the knee following front-foot ground contact.
6. Video cameras with higher frame rates are preferable for measuring 2D angles.

CONCLUSION: Here we have presented evidence supporting the use of video-based 2D measures to assess 3D kinematic lumbar injury risk factors in cricket fast bowlers. The strong correlations and repeatability between the 2D and 3D measures suggest that multiple-plane video analysis is an appropriate and feasible method of measuring 3D kinematics associated with lumbar injury risk. We suggest that cricket coaches should practically apply these findings to lumbar injury risk screening protocols.

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