THE KINEMATIC DIFFERENCES BETWEEN THE LEG-SPIN AND OFF-SPIN BOWLING TECHNIQUES IN CRICKET

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The purpose of this paper was to determine kinematic differences between the off-spin and leg-spin bowling techniques in cricket. The two techniques are often coached similarly; however, a comparative biomechanical analysis of leg-spin and off-spin bowling has not been performed. A 3D Cortex motion analysis system was used to track 52 markers strategically placed on all the major segments of 23 off-spin and 15 leg-spin bowlers of district level. It was found that the two techniques varied in terms of stride length, but other variables which were not previously differentiated in coaching manuals also displayed significant difference. These results highlight potential technique points that will be of benefit when coaching bowlers of each spin direction.

KEY WORDS: Three-Dimensional, Performance, Injury, Alignments, Flight, Swerve

INTRODUCTION: In contrast to the athleticism of fast bowling in cricket which focuses on ball velocity, spin bowling is a more tactical and deceptive art, requiring bowlers to spin the ball in various directions at the highest possible rate. The two main spin delivery types are off-spin, where the ball deviates to the right of the batsman after landing, and leg-spin, where the ball deviates to the left after landing (Beach, Ferdinands and Sinclair, 2012). Research on spin bowling has been restricted to ball kinematics in flight and off the pitch (Beach et al., 2012; Spratford and Davidson, 2010), and elbow kinematics (Chin, Elliot, Alderson, Lloyd and Foster, 2009; Lloyd, Reid, Elliott, and Alderson, 2005; Ferdinands and Kersting, 2007). The only exception is Chin et al. (2009), who tested multiple kinematic variables, although they limited the sample to off-spin bowlers. The coaching manuals generally specify the same set of technical instructions for both off-spin and leg-spin bowling, with only minor differences occasionally stipulated, such as stride length, front knee mechanics, and release position (Cricket Australia, 2005 and 2010). A comparative biomechanical analysis of off-spin and leg-spin could reveal fundamental mechanical differences between these two spin bowling techniques, potentially leading to technique-specific coaching protocols that are more likely to improve performance outcomes and reduce injury risk of spin bowlers. The purpose of this paper was to compare the kinematics of off-spin and leg-spin bowling. It was hypothesized that there would be some key kinematic differences between these two techniques.

METHODS: 23 off-spinners and 15 leg-spinners of district level were tested using, a 14 camera Cortex Motion Analysis System (Motion Analysis Corp., USA) at 200Hz and its inbuilt Kintools RT analyzer, and Kistler force plates (Model 9287BA). After a static trial and adequate warm-up, subjects bowled 24 to 30 deliveries from an over the wicket position in an indoor laboratory, which extended outdoors, allowing them to release the ball so that it landed on a full-length cricket pitch. For motion analysis tacking, spherical reflective markers were used; 52 attached to the body segments, and 3 on the surface of the cricket ball, as specified by Beach et al. (2012). For each bowler, the six deliveries with the highest spin rate were selected for analysis. Joint centers of the body were defined according to protocol of Ferdinands et al. (2007), and calculated as virtual markers in the Cortex software. Marker coordinates were imported into MATLAB (The Mathworks, version 7.14.0) where a script was customized to calculate the linear and joint angular kinematics. The spin of the ball was quantified using the angular velocity vector (Beach et al., 2012). Markers were smoothed using a 14 Hz Butterworth filter. Multiple two-tailed t-tests were performed to test for any significant difference between the off-spin and leg-spin groups using SPSS for Windows (IBM, version 21).

RESULTS: The mean results for the off-spin and leg-spin groups, for the given variables are presented in Table 1.

Table 1. Kinematic characteristics of the leg-spin and off-spin groups (mean ± SD), Statistical significance determined for p < 0.05(*)
BF – Back Foot, FF – Front Foot, BFC – back foot contact, FFC – front foot contact, Release – Ball release, GRF – ground reaction force

Variables	Off-Spin	Leg-Spin	P-value
Ball Velocity (m/s)	18.6 (1.1)	18.8 (1)	0.6
Ball Spin Rate (rev/s)	25 (4.2)	29.3 (4.7)	**<0.01***
Ball Horizontal Spin Angle (°)	-61.6 (12.9)	46.7 (11.7)	**<0.01***
Max BF Horizontal GRF (NM/BW)	0.4 (0.2)	0.4 (0.2)	0.7
Max BF Vertical GRF (NM/BW)	2 (0.4)	2 (0.2)	0.7
Max FF Horizontal GRF (NM/BW)	0.7 (0.4)	1 (0.5)	**0.02***
Max FF Vertical GRF (NM/BW)	1.6 (0.7)	2.3 (0.9)	**<0.01***
BF GRF ratio (horizontal/vertical)	0.2 (0.1)	0.2 (0.1)	0.8
FF GRF Ratio (horizontal/vertical)	0.4 (0.1)	0.4 (0.1)	0.6
Rear Knee Flexion: Max BF Force (°)	45.9 (11.7)	53.4 (8)	**0.04***
Resulting Rear Knee Flexion (°)	23.6 (12.5)	23.1 (10.8)	0.9
Front Knee Flexion: Max FF Force (°)	21.2 (7.4)	22.13 (8.1)	0.7
Front Knee Flexion: Release (°)	18.2 (15.3)	19.5 (13.6)	0.8
Front Knee Extension to Release (°)	-6.7 (15.1)	-2.1 (18.4)	0.4
Shoulder Alignment: BFC (°)	50 (18.3)	46.1 (15.5)	0.5
Hip Alignment: BFC (°)	34.4 (17.2)	32.3 (16)	0.7
H-S Separation: BFC (°)	-15.6 (15.2)	-13.8 (10.6)	0.7
Counter Rotation (°)	41.7 (17.6)	38.3 (14.8)	0.5
Max Hip-Shoulder Separation (°)	29.8 (8.2)	27.3 (10.9)	0.4
Shoulder Alignment: Release (°)	82.9 (27.6)	73.6 (17.7)	0.3
Stride Length (% of stature)	46 (9.9)	52 (5.5)	**0.04***
Stride Angle (°)	17.6 (9.2)	18.9 (7.6)	0.5
Release Height (% of stature)	116.8 (9.9)	117.4 (7.1)	0.5
Elbow Extension To Release (°)	0.7 (14.4)	-11.2 (5.3)	**<0.01***
Max Elbow extension velocity (°/s)	14.6 (437.6)	-314.5 (165.8)	**<0.01***
Trunk Lateral Flexion Angle (°)	31.9 (10)	23.9 (7.5)	**<0.01***
Trunk Anterior Flexion Angle (°)	34.3 (9.8)	39.6 (8.5)	**0.03***
Max Thorax flexion prior to release (°/s)	175.7 (78.8)	102.2 (76.2)	**0.02***
Arm-Thorax angle: Max FF (°)	70.8 (23.6)	63.6 (21.5)	0.4
Shoulder Abduction Release (°)	100.6 (11.1)	105.9 (10.4)	0.2
Max Hip Rotation Velocity (°/s)	520.9	552.6 (176.2)	0.5
Max Shoulder Rotation Velocity (°/s)	972.5	885 (295.7)	0.6
Max Hip Vel. Occurrence (% of delivery)	81.4 (3.7)	78.9 (6.7)	0.2
Max Should. Vel. Occurrence (% of delivery)	96 (3.2)	93.6 (4.8)	**0.02***
Difference (Shoulder - Hip)	14.5 (5)	14.6 (7.1)	0.6

DISCUSSION: The horizontal direction of spin angle determines whether the deliveries were spinning towards the left (positive angle) or right (negative angle) of the target (Beach et al. 2012). The off spin bowlers on average spun the ball to the right of the target (-61.6 ± 12.9º), compared to the leg-spinners, who spun the ball to the left (46.7 ± 11.7º), confirming the categorization of off-spin and leg-spin bowlers. The results also indicate that the leg-spin bowlers spun the ball at a significantly greater speed (29.3 ± 4.7 rev/s) than the off-spinners (25 ± 4.2 rev/s).

All bowling actions, whether fast or slow, are classified in terms of shoulder and hip alignment kinematics and shoulder counter-rotation (Ferdinands, Kersting, Marshall and Stuelcken, 2010). All these variables were similar between the two spin bowling techniques. In general, the off-spin and leg-spin bowlers adopted a semi-open position (a shoulder alignment between 25º and 50º) and counter-rotated the shoulders in excess of 30º, which is indicative of a mixed action. This is contrary to the coaching instruction, which recommends that spinners approach back foot contact with the body aligned side-on to the target (Woolmer, 2009; Tyson, 1985). The amount of hip-shoulder separation at back foot contact was also similar (P = 0.7), although not large enough to cause concern. Of interest is the shoulder alignment at release; both groups having a similarly open position, around 70-80º, enabling the shoulders to effectively contribute to the velocity of the bowling hand through the delivery.

During the back foot contact phase, there were no significant differences between the two styles in terms of the vertical (P = 0.8) and horizontal ground reaction forces (P = 0.8), nor the horizontal to vertical force ratio (P = 0.8). The leg-spinners, however, produced a significantly greater flexion of the rear knee at maximum back foot force (P = 0.04), on average 53.4 ± 8º - the larger the rear knee flexion the greater the amount of force absorption. It is also possible that the leg-spinners may be using the greater knee flexion as a counter-movement phase during delivery stride; but this needs to be investigated further.

During the front foot contact phase, despite no significant difference in the horizontal to vertical force ratio between the two techniques (P = 0.6), the leg-spin bowlers measured significantly greater vertical (P < 0.01) and horizontal braking forces (P = 0.02). Greater force during this phase of the action potentially allows for a larger transfer of energy to the hand. Consequently, while the ball velocities were not different between styles, this may partially explain the larger spin rate of the leg-spin group. While it is evident that off-spinners extended the front knee to ball release (Table 1), the knee was still bent at release (18.1 ± 15.3º), which is contrary to some coaching manuals that recommend bowling over an extended, braced front knee (Cricket Australia, 2005). In addition, there were no significant differences between off-spin and leg-spin bowling in terms of the change in knee angle (P = 0.3) and the flexion angle at release (P = 0.8). Interestingly, even though the braced knee was rarely used, the spin bowlers slightly extended the knee to release, by approximately 2-7º.

It is commonly stated in the coaching literature that off-spinners have a shorter stride length than leg-spinners (Cricket Australia, 2005 and 2010). This was supported by the data: the off-spinners on average having a significantly shorter stride than the leg-spinners (P = 0.03) by an average difference of 5.9% of bowler height.

The arm to thorax separation at the time of maximum front foot force is a kinematic variable, defined such that a lower value corresponds to a greater pre-stretching effect of the shoulder musculature, which potentially leads to a higher velocity and spin rate of the end effector. However there was no significant difference in this variable between the two techniques (P = 0.4), the average value ranging between 60-70º. At release, the abduction angle of the shoulder relates to the velocity contribution of the pelvis and shoulder rotation, such that an optimal angle of 90º places the arm movement in plane with the shoulder and pelvis rotation. However again, there was no difference in this angle between the off-spin and leg-spin bowlers (P = 0.2), both registering slightly greater than the optimal 90º (105.9 ± 10.4º and 100.6 ± 11.1º respectively). It is commonly coached that off-spinners bowl with a vertical arm, and leg-spinners bowl with a less vertical arm (Woolmer, 2009; Tyson, 1985; Cricket Australia, 2010); however, in this study there was no difference in arm abduction angles. It is commonly taught that off-spinners release the ball with a more upright position than leg-spinners; however, the off-spinners bowled with a significantly greater lateral flexion (P < 0.01) and anterior flexion (P = 0.03) than the leg-spinners indicating they were actually less upright. There was also no significant difference in release height between techniques (P = 0.8).

In both the off-spin and leg-spin techniques, there were no significant differences between the maximum values of the shoulder and hip rotation velocity. In terms of segmental

sequencing, there was no difference between the times at which the maximum hip velocity occurred. However, there was a significant difference in the times at which the maximum shoulder velocity occurred. On average, the maximum shoulder velocity occurred earlier in the delivery (93.2%) compared with the off-spinners (96.2%). Furthermore, the maximum velocity of the thoracic flexion to release was significantly greater in the off-spin group.
Lastly, the change in the elbow angle to release was defined such that a positive value indicates an extension of the elbow, whereas a negative value indicates a flexion of the elbow. An extension of the elbow corresponds to a throw-like motion of the bowling arm. Hence, the laws of cricket restrict the amount of elbow extension allowed by a bowler to 15º. The elbow angle between off-spin and leg-spin bowlers was significantly different ($P < 0.01$): the off-spin bowlers generally extending the elbow during their delivery, some even exceeding the legal restriction of 15º; compared to the leg-spinners, generally flexing the elbow to release. It was not previously understood that leg-spinners bowled with a bent arm; a technique that may contribute to the relatively high spin rate produced by these bowlers, particularly since the elbow extension velocity of the leg-spinners (314.5º/s) is much higher than that of the off-spinners (-14.6º/s).

CONCLUSION: In this study, several kinematic variables were found to significantly differ between off-spin and leg-spin bowlers: front foot forces, rear knee flexion, stride length, elbow extension angle and velocity to release, trunk lateral and anterior flexion, thorax flexion velocity to release, and the occurrence of maximum shoulder velocity. It is proposed that some of these could account for the higher spin rate produced by the leg-spin bowlers, as well as the different mechanics between off-spin and leg-spin bowlers. Such research is essential to develop separate coaching protocols for off-spin and leg-spin bowling, correctly acknowledging the significant differences that exist between these bowling techniques.

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