MEASURING SPIN CHARACTERISTICS OF A CRICKET BALL

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The purpose of this paper is to outline an experimental procedure for measuring the spin rate and direction of spin axis of a cricket ball in flight. While the spin rate and horizontal direction of the spin axis are important for deviation upon impact with the ground, the lateral movement of the ball in the air requires a vertical elevation angle of the ball's spin axis. Using three markers on the ball, a 3D Cortex motion analysis system was used to measure the vertical and horizontal components of the spin axis from six deliveries of ten bowlers of varying playing levels. Software was programmed to graphically display the magnitude and direction of the ball spin during the live capture, making it a potentially valuable performance analysis tool. The results show that bowlers had substantial differences in spin rate and spin axis orientation depending on their playing level.

KEY WORDS: cricket, spin bowling, spin, flight, swerve.

INTRODUCTION: In contrast to the athleticism of fast bowling in cricket, spin bowling is a more tactical and deceptive art. While spin bowlers generally aim to deceive batsmen by causing the ball to alter the direction of its bounce off the ground, another effective tactic is to make the ball deviate from its natural projectile motion during its flight. Two factors are commonly associated with the ball's flight, often referred to as dip and drift. The dip of the ball is characterised by non-linear change in the vertical component of flight, the ball increasing its rate of descent towards the ground, similar to a 12-6 curveball in baseball and the kick serve in tennis (Mehta & Pallis, 2001). Drift is characterised by a horizontal deviation in the ball flight, similar to a slice serve in tennis or a curve kick in soccer football (Mehta & Pallis, 2001; Carre´, Asai, Akatsuka, & Haake, 2002). Both can be attributed to the Magnus effect, where a spinning object moving through a fluid creates an asymmetrical pressure distribution, causing a force perpendicular to line of travel (Cross, 2011).
The effect of spin axis, spin direction and spin magnitude on the flight and contact phases of cricket ball is well understood (Wilkins, 1991; Justham, West, & Cork, 2008; Parsons, 2008). However, there have been few attempts to measure these spin properties quantitatively, attempts that have employed different methods and often recruited low subject numbers (Justham et al., 2008; Chin, Elliot, Alderson, Lloyd, & Foster, 2009; Spratford & Davison, 2010). The ability to measure the kinematic properties of ball spin will provide coaches with a quantitative assessment of the some of the most important spin bowling performance variables, information that is essential for the provision of objective feedback to bowlers on their performance. The purpose of this paper was to develop a methodology that could accurately measure the 3D kinematics of the spinning cricket ball, further applying this methodology to assess the spin bowling performance of a sample of spin bowlers.

METHODS: Ten bowlers of club and state level were tested using a 14 camera Cortex Motion Analysis System (Version 2.5, Motion Analysis Corporation Ltd., USA) at 200 Hz, and the inbuilt Kintools RT analyser. Subjects bowled twenty-four to thirty deliveries from their respective over the wicket position to a right-handed batsmen in an indoor laboratory, which extended outdoors to a full-length cricket pitch. The data from the left arm bowlers was converted to right arm data.
The ball was captured using a system of three reflective, spherical markers attached directly to the ball surface. They were placed at one hundred and twenty degree intervals around the face, three centimetres from the centre of the face (Figure 1). Markers were replaced if any damage or movement occurred.

Figure 1: Showing the three dynamic markers.

The ball segment was created using the skeleton builder function of the Kintools RT software to calculate the ball's angular velocity, which was then separated into components about the horizontal and vertical spin axes.

Six deliveries were analysed for each subject. The direction of spin was calculated by projecting the spin axis onto the horizontal and measuring the angle between that and the lateral axis (Figure 2a). The elevation of the ball axis was defined as the angle between the axis of spin and the horizontal (Figure 2b), with both angles measured in respect to the direction of ball velocity.

The centre of mass of the ball was calculated using two additional markers placed on the intersection of the quarter and half seams during a static trial, directly opposite to each other. A virtual dynamic centre of mass was then created with respect to the three dynamic markers from which the linear velocity of the ball was calculated. Marker coordinates were smoothed using a Butterworth filter at 30 Hz.

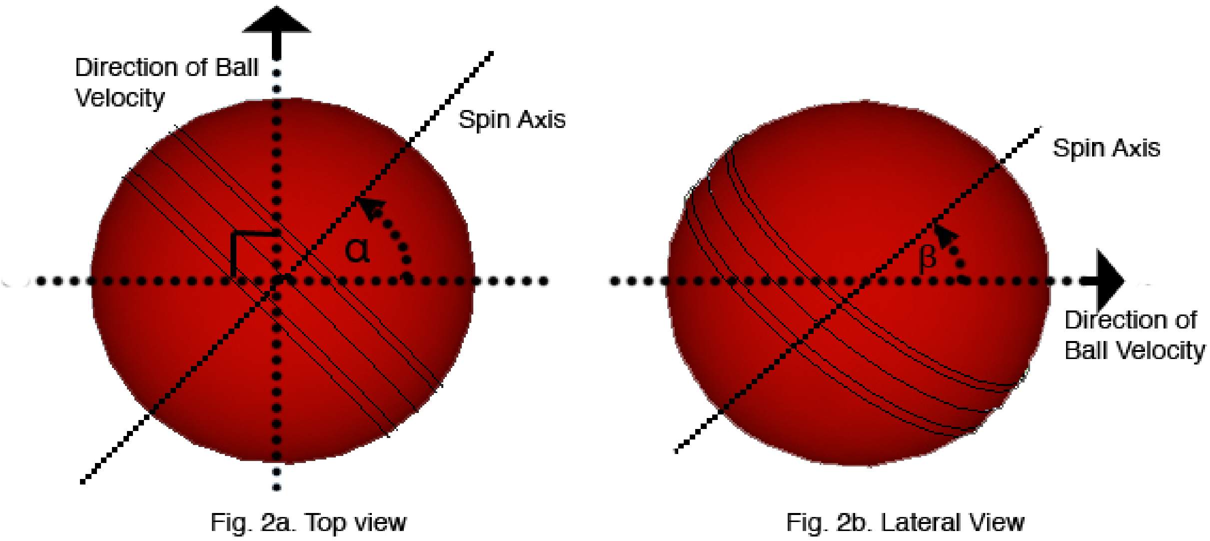

Figure 2: A). View from a top aspect for Leg Spin bowlers. Direction angle (α) represents the angle of rotation from perpendicular to direction of ball velocity such that a top spinning delivery is 0º. Off spin bowlers are a mirror image represented as a negative value in the results. B) View from lateral aspect, Elevation angle (β) measured in respect to the direction of travel with positive values representing anti-clockwise rotation.

RESULTS: The bowling sample was classified into two main categories: high performance level, including bowlers of first grade level or above; low performance level, including bowlers of 3rd grade club level or below, with their results displayed in Table 1.

Table 1: Results for the listed parameters (±SD). Player competition level is indicated by: * state squad player, # first grade club level, ^ retired first class players, φ 3rd grade club level, ξ part time, low grade bowler.

Subject	Delivery type (n)	Ball speed (m s^{-1})	Spin rate (rev s^{-1})	Direction (º)	Elevation (º)
3*	Off-spin (6)	19.8 ±0.35	27.2 ±1.03	-48.2 ±3.2	11.4 ±2.7
1#	Off-spin (6)	19.5 ±0.01	26.8 ±1	-62 ±3.2	14.8 ±2
4#	Off-spin (6)	18.1 ±0.37	28.3 ±0.05	-60.4 ±3.27	2.6 ±2.3
5^	Off-spin (6)	19 ±0.02	27.5 ±1.3	-63.5 ±6.14	12.6 ±0.92
2φ	Off-spin (6)	16.9 ±0.01	20.2 ±0.04	-64.9 ±3.8	17.1 ±0.7
6ξ	Off-spin (6)	17.2 ±2.8	16.4 ±0.13	-126.8 ±30.3	12.1 ±7.26
10^	Leg-spin (6)	17.5 ±0.26	29.2 ±0.09	50.0 ±5.6	-8.2 ±7.03
7φ	Leg-spin (6)	18.2 ±0.02	27.9 ±0.06	37.7 ±6.4	17.1 ±1.88
8φ	Leg-spin (6)	20.1 ±0.58	24.4 ±0.09	27.2 ±1.56	-16.3 ±3.8
9φ	Leg-spin (6)	18.6 ±0.66	24.9 ±0.04	43.7 ±13.5	9 ±2.4

DISCUSSION: The spin bowlers from the high performance group tended to produce higher spin rates than those from the low performance group. Spin bowlers in the higher performance group produced spin rates in excess of 26.8 rev.s^{-1}, whereas the spin rates of the low performance group were generally below 24.9 rev.s^{-1}, the only exception being Bowler 8, a leg-spinner, producing 27.9 rev.s^{-1} (Table 1). This finding is consistent with previous studies. Justham et al. (2008) found that the English national spin bowlers produced higher spin rates, 29.5 ±1.4 rev.s^{-1}, than spin bowlers from the ECB development squad bowlers, 25.9 ±5.4 rev.s^{-1}. Chin et al. (2009) also found that spin bowlers from an elite playing level produced higher spin rates, 26.7 ±4.6 rev.s^{-1}, than those from a high performance group, 22.2 ±3.8 rev.s^{-1}. Hence, it is evident that spin rate is an important determinant of spin bowling performance, something that can be potentially used to identify prospective talent. Furthermore, the training of spin bowlers to optimize their spin rates should be encouraged in coaching programs.

Spin bowlers generally bowl slower than fast bowlers, a certain proportion of the bowling hand's kinetic energy used to produce frictional forces between the fingers and ball in order to impart spin on the ball. Hence, the range of ball speeds ranged from 16.9–20.1 m.s^{-1}, much smaller than the corresponding range for fast bowlers measured in the lab, typically ranging from 37–40 m.s^{-1} (Bartlett, Stockill, Elliott, & Burnett, 1996). The high performance off-spin bowlers delivered the bowl with velocities above 18.1 m.s^{-1}, while those in the low performance group produced velocities less than 17.2 m.s^{-1}. This is consistent with the studies of Justham et al. (2008) and Chin et al. (2009), both finding that the ball velocities of off-spinners were faster in the higher performance levels. However, this case was reversed for the leg-spinners in this study, the one higher performance leg-spinners producing slightly lower ball speeds than the three lower performance leg-spinners.

There is much variation in spin direction, even within bowling types in the sample. Generally, the off-spinners had higher spin direction angles than the leg-spinners, indicating that the off-spinners produced a larger component of side-spin, whereas the leg-spinners produced a larger component of top-spin (Table 1). There is no one preferred spin direction in spin bowling. Higher components of side-spin potentially create more lateral deviation off the pitch. In contrast, higher components of top-spin produce less lateral deviation off the pitch, but gain the advantage of producing more drop in flight, a factor that can cause the batsman to misjudge the flight of the ball. Some bowlers prefer to produce both these characteristics, a strategy employed by two High Performance bowlers (Bowlers 1 and 7), who utilized an average spin direction of 48.2° and 50.0°, respectively; angles that produce approximately equal components of lateral deviation off the pitch and drop in the ball's flight.

Of all the spin performance variables, spin elevation angle had the most variation with no systematic trend evident between performance levels or spin bowling type. This is a very important result. The variation in this variable signifies that each of the bowlers had potentially different abilities to generate swerve and drop. Larger spin elevation angles are more conducive to the production of swerve while lower spin elevation angles, in contrast, are more conducive to the production of drop.

It is traditionally thought that leg-spinners have the potential to swerve the ball to the right (the leg-side); however, two of the leg-spinners in this sample achieved negative elevation angle, giving them the potential to swerve the ball to the left. Such a characteristic has not been previously reported in the cricket literature. Interestingly, none of the off-spinners could achieve a negative elevation. This ability may be the exclusive domain of leg-spinners alone. It may even be feasible to train leg-spin bowlers to spin balls in the same direction, but with both positive and negative elevation angles, giving them the ability to swerve a ball to the left and right, even though it has the same direction of spin.

The methodology used in this study allows for the quick calculation of ball speed and spin rate during the test session, potentially providing the coach and player with rapid feedback on these performance characteristics. The presentation of timely feedback to the athlete has been shown to increase the level of skill acquisition, particularly if this feedback is presented clearly and visually. In this study, the three-dimensional spin axis graphically was represented on the computer screen, clearly depicting the direction and elevation of spin, something that can be used by coaches to provide feedback to their bowlers.

CONCLUSION: In this study, a methodology was developed to calculate the three-dimensional angular velocity characteristics of a spinning ball. This method was successfully implemented to analyse the spin rate of rotation, spin direction and spin elevation angle of a sample of spin bowlers, showing clearly that these are important determinants of spin bowling performance. It was also found that a leg-spin bowler has the potential to swerve a ball either left or right, independent of spin direction. Furthermore, the software was programmed to provide prompt feedback to the bowler, a property that is important for skill acquisition, giving bowlers the opportunity to modify their deliveries under the instruction of a qualified coach.

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