THE EFFECT OF PERFORMANCE LEVEL ON INITIAL BALL FLIGHT KINEMATICS IN ELITE AND PATHWAY WRIST-SPIN BOWLERS

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The aim of this study was to provide foundation knowledge for 3D ball kinematics for elite and pathway wrist-spin (WS) bowlers, enabling performance measures that discriminate between skill levels to be identified. Results indicated that elite bowlers deliver the ball with significantly higher velocity and spin axis azimuth angle and with a lower seam azimuth angle. These differences all have the potential to positively influence the flight characteristics, and as such can be used as performance measures to discriminate between skill levels of cricket spin bowlers.

KEY WORDS: Magnus effect, spin-rate, seam, spin axis, cricket.

INTRODUCTION: Bowling is a fundamental aspect of cricket with techniques broadly categorised as either spin or fast bowling. Spin bowlers can be further classified as finger-spin (FS) or the less common wrist-spin (WS), named to reflect the end point of the body's kinetic chain responsible for placing revolutions on the ball (Wilkins, 1991; Woolmer, Noakes, & Moffett, 2008). In comparison to fast bowling, very little research exists for spin bowling, and to date, there is no published biomechanical research investigating elite level WS bowlers. A right-handed WS bowler places anticlockwise ball rotations, with the seam rotated and directed laterally to the off-side or to the right of a right-handed batsman (this can be seen in Figures 2a and 2b).

As they deliver the ball significantly slower than their fast bowling counterparts, WS bowlers must rely on an array of skills to influence the contest, including an ability to control the ball via deflection laterally (drift) and vertically (dip) during flight, combined with deviation from the pitch after bounce (side-spin) (Bradman, 1969; Tyson, 1994; Wilkins, 1991; Woolmer et al., 2008). Drift and dip are controlled via the aerodynamic principle termed the Magnus effect, which applies lift and drag forces perpendicular and opposite to the linear velocity vector of a smooth spinning object (Robinson & Robinson, 2013). The magnitude of this force is proportional to the projectile velocity, rate of rotation and the angle between the ball's projectile velocity vector and spin axis (Mehta, 1985; Robinson & Robinson, 2013; Watts & Ferrer, 1987). In addition to affecting in-flight ball deflection, bowling coaches commonly suggest, the amount of "side-spin" experienced by a ball following contact with the pitch is influenced by; rotation imparted on the ball at ball release (BR), the stability of the seam during flight and the orientation of the seam at bounce (Bradman, 1969; Woolmer et al., 2008). Coaches theorise that a seam azimuth angle closer to orthogonal to the direction of flight will facilitate a greater angle of resultant side-spin (Bradman, 1969; Wilkins, 1991). It must be noted, that no peer reviewed research exists substantiating these claims. Therefore, the purpose of this study was quantify three dimensional (3D) ball kinematics inclusive of; BR speed, spin rate, and orientation of the spin axis and seam in elite (currently competing at a minimum of 1st Class up to and including Test level) and pathway (currently competing at a minimum level of state U19, up to and including List A level (open age national 1-day level)) WS bowlers. It was anticipated that ball kinematic variables would discriminate between skill levels allowing for performance measures to be identified and foundation data compiled.

METHODS: Twenty elite male WS bowlers were selected by the Australian national spin bowling coach to participate in this study and assigned to either elite (n=7, 29.6 ± 7.8 years, 180.2 ± 4.2 cm, 71.8 ± 8.0 kg) and pathway (n=13, 19.6 ± 3.6 years, 179.6 ± 6.9 cm, 71.0 ± 8.0 kg). Participants represented the entire population of bowlers at these levels within Australia. Data collection took place in an indoor motion capture laboratory purpose built for cricket analysis and contained a full length artificial pitch. Ball flight variables were collected using seven retro-reflective markers attached to the ball, four evenly distributed around the seam and three dynamic hemispherical markers comprised of ultralight foam (<0.1g) affixed in locations that did not impede the bowler's preferred grasp. Each ball used underwent a static calibration to allow for the construction of a standardised 3D ball coordinate system. This involved storing the location of the four seam markers in the static calibration trial with reference to a technical coordinate system (TCS) created from the three hemispherical markers that remained on the ball during static and dynamic bowling trials. The location of the seam markers (removed for the bowling trials) was virtually reconstructed in all dynamic trials with respect to the TCS created using the three dynamic hemispheric markers.
Marker trajectories were tracked using a 22-camera (MX 13 and 40) Vicon MX motion analysis system (Oxford Metrics, Oxford, UK) operating at 250 Hz. The reconstruction volume encompassed the delivery stride until approximately 3m post release. Participants warmed up as per their normal pre game routine and bowled six overs (36 deliveries) with a two minute break between each to replicate match conditions. Participants were asked to nominate where their usual deliveries would pass a right-handed batsman based on a clear target that consisted of a series of 25 cm x 25 cm grids (accuracy target). Aside from those that struck the target directly, deliveries that impacted a grid directly above, underneath, or horizontally adjacent to the nominated grid on the off-side (to the batsman's right) were considered successful deliveries. Data from the first six successful deliveries were then modelled using a customised ball model based on previous validated work (Jinji & Sakurai, 2007; Sakurai, Reid, & Elliott, 2013; Whiteside, Chin, & Middleton, 2012) that was extended to incorporate ball seam kinematics. Ball velocity, spin rate, seam stability and spin axis' orientation in each delivery were computed using the data collected from the BR frame and the 30 frames (0.12 sec) thereafter. Given the potential variability of the movement of the seam post release, seam angles (azimuth and elevation) were treated as discrete variables from the mean of three frames (0.012 sec) post-BR. Seam stability was measured as the acute angle between the angular velocity vector and the plane of the seam and expressed as a percentage where a value of 100 denoted the theoretical condition of perfect stability, whereby the ball's x-axis and angular velocity vector were coincident. Conversely, a value of zero denoted perfect instability of the seam (more commonly termed a scrambled seam). Measurement conventions can be seen in Figures 1a, 1b and 1c.

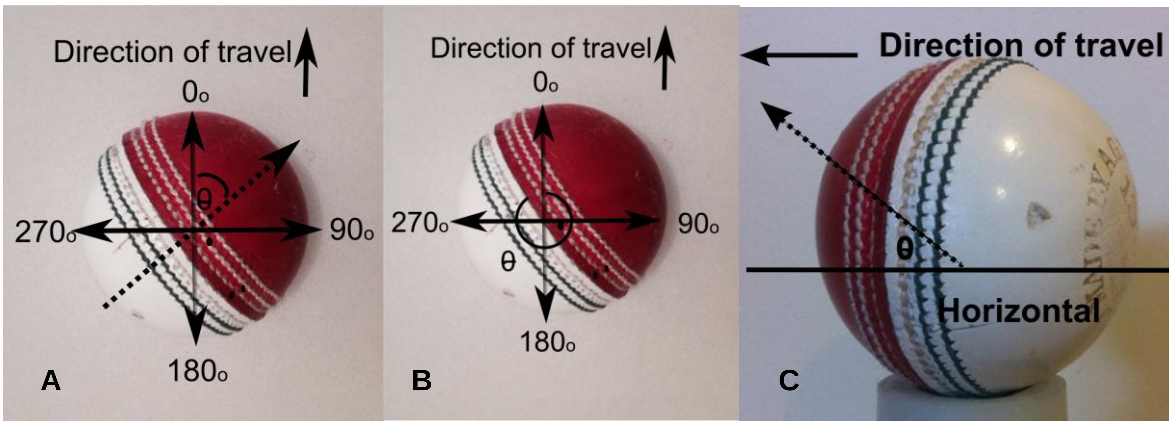

Figure 1a. A superior view of the spin axis azimuth angle, whereby ($\theta_{\vec{\omega}}$) is the angle measured between the angular velocity vector (dotted line) and the x-axis of the global.

Figure 1b. A superior view of the seam axis azimuth angle, whereby (θ_{Seam}) is the angle measured between the plane of the seam and the x-axis of the global CS.

Figure 1c. A sagittal view of the spin axis elevation angle, whereby $\varphi_{\vec{\omega}}$ is the angle measured between the angular velocity vector (dotted line) and the horizontal plane of the global CS.

Independent sample t-tests were performed to establish differences between elite and pathway WS groups (α < 0.05). Effect sizes (*d*) were calculated to functionally differentiate between groups, with levels of, 0.2, 0.5 and 0.8 representing small, moderate and large effects respectively (Cohen, 1992).

RESULTS: Compared with developing WS bowlers, elite WS bowlers generated significantly higher ball velocity (p = 0.015; d = 1.28), and significantly lower seam azimuth (p = 0.017; d = 1.39) and spin axis azimuth angles (p = 0.021; d = 0.30). Spin axis elevation angle and spin rate, while not significantly different (p = 0.107 and 0.058) returned large effect size differences (d = 0.83 and 1.00 respectively) (Table 1).

Table 1. Mean (± SD) ball kinematics for WS bowlers.

Variable	Pathway	Elite	*p*	*d*
Ball velocity (m/s)	18.6 (0.7)	19.5 (0.7)	0.015*	1.28
Spin rate (rev/s)	34.3 (4.0)	38.7 (4.9)	0.058	1.00
Spin axis azimuth (°)	41.2 (14.5)	39.0 (7.1)	0.021*	0.30
Spin axis elevation (°)	3.0 (4.9)	7.9 (4.8)	0.107	0.83
Seam azimuth (°)	314.0 (15.3)	297.7 (2.7)	0.017*	1.39
Seam elevation (°)	76.0 (5.6)	73.1 (5.7)	0.313	0.51
Seam stability (%)	74 (15)	75 (10)	0.933	0.08

*Significant p<0.01

DISCUSSION: The aim of this study was to provide foundation knowledge for 3D ball kinematics for elite and pathway WS bowlers, enabling performance measures that discriminate between skill levels to be identified. Compared with pathway bowlers Elite bowlers delivered the ball with a higher velocity, spin rate, axis elevation and also with a lower axis azimuth and seam azimuth (Figures 2a and 2b) angles. Theoretically these differences will affect the flight characteristics of the ball, both pre and post ball-pitch contact. Increases in BR velocity, spin rate and spin axis azimuth angle will also cause the ball to have greater drift and dip due to the subsequent increases in the Magnus force applied to the ball (Mehta, 1985; Robinson & Robinson, 2013; Watts & Ferrer, 1987). The lower seam azimuth angle (seam is closer to orthogonal to the direction of travel) coupled with increased rates of spin observed by elite bowlers theoretically suggests that, if the ball produces side-spin in the direction of the rotating seam, the direction of the ball will travel at a more acute angle, and have the effect of spinning further away from a right-handed batsman.

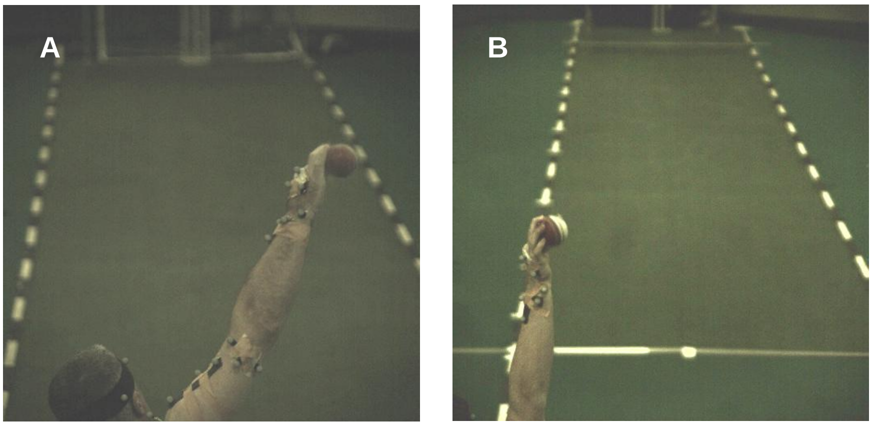

Figure 2a. A pathway bowler with a large seam azimuth angle
Figure 2b. An elite bowler (over 200 test wickets) with a smaller seam azimuth angle

The increase in the axis of elevation angle would also subsequently see a higher zenith location during flight, in turn increasing the post bounce reflection angle based on the law of reflection (James, Carre, & Haake, 2004). In a cricketing sense, these differences make a WS bowler more difficult for a batsman to face and score runs, thus increasing the chances of the bowler in dominating the contest. As such, coaches should encourage bowlers to deliver the ball with the seam rotated further to the off-side, with more flight and attempt to place more revolutions on the ball. It is hoped that future research will attempt to link technique, strength and anthropometry variables to ball kinematics.

CONCLUSION: Results from this study show that ball kinematic differences exist between elite and pathway WS bowlers and as such can be used as performance measures to discriminate between skill levels and be used in future WS research.

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