A KINEMATIC COMPARISON OF CONVENTIONAL INSWING AND OUTSWING BOWLING IN CRICKET

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Swing bowling is an important facet of cricket, however, it has received little consideration from researchers. This study compared the bowling action and initial ball flight kinematics of inswing and outswing deliveries in 15 (male = 12, female = 3) pathway and high-performance medium and fast pace bowlers. Participants delivered the ball with their forearm, hand and the seam of the ball angled towards and away from the batter for inswing and outswing with an extended wrist flexing at ball release. Therefore, significant differences were found in forearm orientation ($p < 0.001$), hand orientation ($p < 0.001$), seam azimuth angle ($p < 0.001$) and swing angle ($p < 0.001$). By identifying similarities and differences of inswing and outswing, this study could benefit coaches to improve swing bowling performance in bowlers and provide a foundation for future research.

KEYWORDS: cricket, swing bowling, kinematics, performance.

INTRODUCTION: Fast bowlers use swing to laterally deviate the ball during flight towards (inswing) or away (outswing) from the batter's body. Sarpeshkar, Mann, Spratford, and Abernethy (2017), found that in comparison to straight deliveries, swinging deliveries reduced the performance of batters by delaying movements of the hitting action and reducing the quality of bat and ball contact. Additionally, researchers found that outswing deliveries further decreased batting performance in comparison to inswing deliveries. Despite this, the ability to bowl both inswing and outswing deliveries may help to exploit weaknesses that batters may have (Woolmer, Noakes, & Moffett, 2008). To produce swing, the bowling action must create asymmetric airflow surrounding the ball, whereby airflow is turbulent around one side and laminar on the other to create a pressure differential, producing a transverse force causing the ball to swing (Mehta & Wood, 1980).

While off-spin and leg-spin bowling actions have been compared (Beach, Ferdinands, & Sinclair, 2016), no research has compared inswing and outswing. Currently, only Lindsay and Spratford (2020) have described the techniques in published literature, corresponding with that presented by Woolmer et al. (2008) in a coaching manual. An outswing technique is described as having a cocked wrist, in extension, with the seam angled away from the batter. The arm is slightly rounded (reduced shoulder abduction) and the wrist flexing through ball release. Inswing is described as having a cocked wrist, in extension, with the seam angled towards the batter. The arm is more upright (increased shoulder abduction) with a strong push of the wrist, acting as an extension of the forearm. Wind tunnel studies (Barton, 1982; Bentley, Varty, Proudlove, & Mehta, 1982) have recommended that the seam be angled 10° - 30° in the direction of swing, however, delivery speed, ball revolutions and seam azimuth angle should not differ as these variables do not influence swing direction.

Currently, no research compares inswing and outswing bowling kinematics and wind tunnel studies may not replicate in-vivo bowling and further research is required. Therefore, this study aimed to compare the bowling action and initial ball flight kinematics of inswing and outswing deliveries. It was hypothesised that the forearm would be angled towards and away from the batter for inswing and outswing, therefore, causing the hand to be angled in the same direction. Furthermore, this technique would likely produce a seam angle towards and away from the batter for inswing and outswing, causing swing in the same direction.

METHODS: Fifteen (female = 3, male = 12) pathway (state u19) and high-performance (senior state) medium and fast pace bowlers (age 20.0 ± 3.3 years, mass 78.8 ± 11.0 kg, height 181.7 ± 9.2 cm) participated in this study. Ethics approval was granted for this study

by the institutional ethics committee and informed consent was provided by participants. Thirty-eight retro-reflective markers were placed on the upper-body of participants (Campbell, Lloyd, Alderson, & Elliott, 2009; Chin, Lloyd, Alderson, Elliott, & Mills, 2010; Lloyd, Alderson, & Elliott, 2000), allowing bowling action kinematics to be calculated. To calculate ball kinematics, three retro-reflective tape patches were placed on the sides of new Kookaburra Club Match cricket balls (Sakurai, Reid, & Elliott, 2013; Spratford et al., 2017; Whiteside, Chin, & Middleton, 2013). An indoor training facility with artificial wickets and enough space for full-length run-ups was used for data collection. Participants used one new ball per pair and bowled three alternating overs per bowler containing a total of nine inswing and nine outswing deliveries, randomised between participants. Bowlers were instructed to deliver the ball at a full length and match intensity as though bowling to a batter of the same handedness. A 17-camera Vicon motion analysis system (Oxford Metrics Ltd., Oxford, UK) sampling at 250 Hz captured marker trajectories. Two Samsung (Galaxy S7) high-speed video cameras capturing 260 frames per second, located behind the stumps at the bowler's end and orthogonal to the wicket at the batter's end, captured ball pitch locations.
For swing calculation, ball pitch coordinates were determined using Kinovea software v0.8.27 (Kinovea Organisation, Bordeaux, FR) and markers positioned at known distances from the stumps. Vicon Nexus software (Oxford Metrics Ltd., Oxford, UK) was used to reconstruct and label upper-body marker trajectories. A fourth-order zero-lag Butterworth filter with a cut-off frequency of 12 Hz filtered marker trajectories before being modelled using the University of Western Australia upper-body model (Campbell et al., 2009; Chin et al., 2010; Lloyd et al., 2000) to calculate kinematics. Bowling action data were extracted and reported at BR, defined as the frame when the distance between the hand and ball markers increased by more than 20 mm relative to the previous frame. Left-handed data were converted to right-handed for comparisons between bowlers. Thorax rotation and forearm and hand orientation were measured in the z-axis of the global system with zero degrees orientated down the wicket, increasing positively anticlockwise and negatively clockwise. Shoulder abduction was measured relative to the thorax and wrist extension increased negatively.
Each new cricket ball underwent a static calibration with four spherical markers evenly placed around the seam. Prior to bowling, the seam markers were removed and virtually recreated during the trials, allowing the seam to be replicated. Marker trajectories were then reconstructed, labelled and modelled (Sakurai et al., 2013; Spratford et al., 2017; Whiteside et al., 2013) to calculate kinematics. The coordinates of the ball at BR, the average of two frames post-BR and ball pitch location were used to calculate swing angle (Lindsay & Spratford, 2020; Figure 1). Deliveries were deemed to have swung if there was a difference in angle between the vectors with the corresponding angle defined as swing. Positive angles represented outswing and negative angles represented inswing. Seam stability was calculated to determine how stable the seam plane remained during flight. Values of 100% and 0% represented perfect stability and instability (cross-seam delivery) receptively (Spratford et al., 2017).

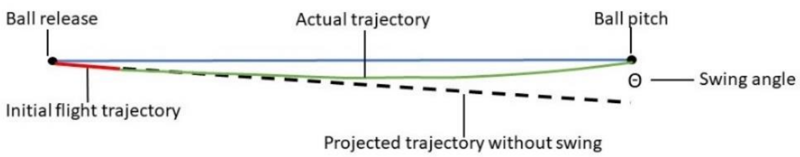

Figure 1. Schematic of an outswing delivery swing angle calculation.

SPSS v26 (IBM Statistics, Chicago, USA) was used to perform statistical analyses. Means and standard deviations were calculated, and paired samples t-tests were used to determine significant differences between inswing and outswing with the alpha level set at $p \leq 0.05$. Cohen's effect sizes (ES) functionally differentiated between groups, with 0.2, 0.5 and 0.8 representing small, moderate and large ES respectively (Cohen, 1992).

RESULTS: When inswing and outswing results were compared (Table 1), significant differences presented in forearm orientation ($p < 0.001$), hand orientation ($p < 0.001$), seam azimuth angle ($p < 0.001$) and swing ($p < 0.001$).

Table 1. Comparison of inswing and outswing bowling actions and ball flight kinematics.

Variable	Inswing	Outswing	*p*-value	Effect size
Thorax rotation (°)	24.6 ± 9.9	27.4 ± 7.2	0.466	0.323
Shoulder abduction (°)	103.7 ± 10.8	104.0 ± 6.9	0.991	0.033
Forearm orientation (°)	-14.7 ± 5.9	16.2 ± 9.4	<0.001*	3.938†
Wrist extension (°)	-36.1 ± 12.7	-41.2 ± 12.3	0.241	0.401
Wrist angular velocity ($°·s^{-1}$)	744.4 ± 290.6	815.4 ± 277.0	0.472	0.250
Hand orientation (°)	-15.2 ± 5.9	12.5 ± 6.7	<0.001*	4.388†
Release speed ($m·s^{-1}$)	30.3 ± 3.3	29.0 ± 2.1	0.578	0.470
Seam stability (%)	23.4 ± 10.8	21.9 ± 11.7	0.784	0.133
Seam azimuth angle (°)	24.6 ± 16.8	339.2 ± 13.2	<0.001*	3.005†
Ball angular velocity ($rev·s^{-1}$)	18.5 ± 2.1	19.1 ± 2.1	0.501	0.285
Swing (°)	-0.4 ± 0.6	0.7 ± 0.6	<0.001*	1.833†

*Indicates $p \leq 0.05$, †indicates large ES ≥ 0.80.

DISCUSSION:

In this study, forearm and hand orientation as well as seam azimuth angle and swing were significantly different between inswing and outswing. Due to the close link between forearm and hand orientation as well as seam azimuth angle and swing, it is believed that forearm orientation caused the hand to be angled in the same direction, producing a seam azimuth angle and swing towards and away from the batter for inswing and outswing respectively.

When comparing inswing and outswing bowling actions, forearm and hand orientation were significantly different, consistent with Woolmer et al. (2008). Bowlers delivered inswing with their forearm (-14.7 ± 5.9°) and hand (-15.2 ± 5.9°) angled towards the batter and outswing with their forearm (16.2 ± 9.4°) and hand (12.5 ± 6.7°) angled away from the batter. This is consistent with spin bowling studies that found forearm and hand orientation can alter the ball spin axis (Beach et al., 2016; Chin, Elliott, Alderson, Lloyd, & Foster, 2009). In terms of swing bowling, gripping the ball with the seam parallel to the second and third phalanges and angling the forearm and hand would angle the seam in the same direction. However, former players suggest a grip with the seam angled across the phalanges (Pyke & Davis, 2010), allowing bowlers to deliver the ball with their forearm and hand oriented straight towards the batter. However, grips were not measured across participants, offering a limitation to the conclusions as differences in grips could cause variance in results.

No significant differences were found in shoulder abduction, wrist extension and wrist angular velocity measures. These findings are not consistent with Woolmer et al. (2008) who proposed that bowlers should employ an upright arm (greater shoulder abduction) and a rounded arm (reduced shoulder abduction) for inswing and outswing deliveries. However, more recently, it has been discussed that bowlers may use smaller changes in their bowling action to deceive batters and may use different ball grips, wrist or hand positions to account for the limited change in shoulder abduction (Pyke & Davis, 2010). Furthermore, despite Woolmer et al. (2008) recommending differences in wrist kinematics, wrist extension (-36.1 ± 12.7° and -41.2° ± 12.3°) and angular velocity (744.4 ± 290.6$°·s^{-1}$ and 815.4 ± 277.0$°·s^{-1}$) measures were not significantly different between inswing and outswing deliveries, indicating that bowlers should use the same wrist action for both swing directions.

The seam azimuth angles were significantly different for inswing (24.6 ± 16.8°) and outswing (339.2 ± 13.2°), causing the deliveries to swing 0.4 ± 0.6° towards and 0.7 ± 0.6° away from the batter for inswing and outswing. Each degree of swing equates to a lateral displacement of approximately 16.5 cm, 20 cm and 23 cm when the ball pitches 6 m, 4 m and 2 m from the batter's stumps. While the seam azimuth angles were within the suggested range of 10° - 30° (Barton, 1982; Bentley et al., 1982), seam stability was low (23.4 ± 10.8% and 21.9 ± 11.7%) with a value of 100% representing perfect stability. This factor likely limited swing by reducing airflow asymmetry around the ball (Barton, 1982; Bentley et al., 1982). The low seam stability and swing may be explained by the bowlers having limited exposure to swing bowling coaching, offering a further limitation.

In the current study, inswing and outswing techniques were mirrored with the forearm, hand and seam angled towards and away from the batter for inswing and outswing respectively.

Based on these findings and previous coaching literature (Pyke & Davis, 2010; Woolmer et al., 2008), it is recommended that coaches instruct bowlers to deliver the ball in one of two ways. Firstly, with the ball gripped parallel to the fingers and delivered with the forearm and hand angled towards or away from the batter, or secondly, with the ball gripped across the fingers and delivered with the forearm and hand orientated straight down the wicket. It is important to note that both techniques should produce a seam azimuth angle in the direction of intended swing. Thorax rotation, shoulder abduction and wrist kinematics should not differ for inswing and outswing. Overall, when coaching swing bowling, coaches should focus on ball grip and hand orientation due to the close relation to forearm orientation.

CONCLUSION: Four kinematic variables were found to be significantly different between inswing and outswing bowling: forearm orientation, hand orientation, seam azimuth angle and swing angle. When coaching inswing and outswing techniques, coaches should focus on small modifications in hand position and ball grip to angle the seam in the direction of intended swing (towards or away from the batter). Bowlers in this study delivered the ball with their forearm and hand angled in the direction of swing, likely to angle the seam in the same direction, however, as different ball grips have been suggested, future research should investigate which grip is optimal for swing bowling. Additionally, research investigating whole-body kinematics and the entire bowling action could benefit coaches further.

REFERENCES

Barton, N. (1982). On the swing of a cricket ball in flight. *Proceedings of the Royal Society of London. A. Mathematical and Physical Sciences, 379*(1776), 109-131.

Beach, A., Ferdinands, R., & Sinclair, P. (2016). The kinematic differences between off-spin and leg-spin bowling in cricket. *Sports Biomechanics, 15*(3), 295-313.

Bentley, K., Varty, P., Proudlove, M., & Mehta, R. (1982). An experimental study of cricket ball swing. *Imperial College Aero Technical Note*, 82-106.

Campbell, A., Lloyd, D., Alderson, J., & Elliott, B. (2009). MRI development and validation of two new predictive methods of glenohumeral joint centre location identification and comparison with established techniques. *Journal of Biomechanics, 42*(10), 1527-1532.

Chin, A., Elliott, B., Alderson, J., Lloyd, D., & Foster, D. (2009). The off-break and “doosra”: Kinematic variations of elite and sub-elite bowlers in creating ball spin in cricket bowling. *Sports Biomechanics, 8*(3), 187-198.

Chin, A., Lloyd, D., Alderson, J., Elliott, B., & Mills, P. (2010). A marker-based mean finite helical axis model to determine elbow rotation axes and kinematics in vivo. *Journal of Applied Biomechanics, 26*(3), 305-315.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155.

Lloyd, D., Alderson, J., & Elliott, B. (2000). An upper limb kinematic model for the examination of cricket bowling: A case study of Mutiah Muralitharan. *Journal of Sports Sciences, 18*(12), 975-982.

Lindsay, C., & Spratford, W. (2020). Bowling action and ball flight kinematics of conventional swing bowling in pathway and high-performance bowlers. *Journal of Sports Sciences, 38*(14), 1650-1659.

Mehta, R., & Wood, D. (1980). Aerodynamics of the cricket ball. *New Scientist, 87*(1213), 442-447.

Pyke, F., & Davis, K. (2010). *Cutting Edge Cricket*: Human Kinetics.

Sakurai, S., Reid, M., & Elliott, B. (2013). Ball spin in the tennis serve: spin rate and axis of rotation. *Sports Biomechanics, 12*(1), 23-29.

Sarpeshkar, V., Mann, D., Spratford, W., & Abernethy, B. (2017). The influence of ball-swing on the timing and coordination of a natural interceptive task. *Human Movement Science, 54*, 82-100.

Spratford, W., Whiteside, D., Elliott, B., Portus, M., Brown, N., & Alderson, J. (2017). Does performance level affect initial ball flight kinematics in finger and wrist-spin cricket bowlers? *Journal of Sports Sciences, 36*(6), 651-659.

Whiteside, D., Chin, A., & Middleton, K. (2013). The validation of a three-dimensional ball rotation model. *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 227*(1), 49-56.

Woolmer, B., Noakes, T., & Moffett, H. (2008). *Bob Woolmer's Art and Science of Cricket*: Struik Pub.

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