MOVEMENT VARIABILITY IN ELBOW AND WRIST KINEMATICS OF NEW BALL OUTSWING BOWLING IN CRICKET FAST BOWLERS

Cody Lindsay[1], Rian Crowther[2], Kane Middleton[3], Brad Clark[1], John Warmenhoven[4] and Wayne Spratford[1]

University of Canberra Research Institute for Sport and Exercise, University of Canberra, ACT, Australia[1]

Cricket Australia, National Cricket Centre, QLD, Australia[2]

Sport, Performance, and Nutrition Research Group, School of Allied Health, Human Services and Sport, La Trobe University, VIC, Australia[3]

School of Sport, Exercise and Rehabilitation, University of Technology Sydney, NSW, Australia[4]

This study investigated between-bowler movement variability of wrist and elbow kinematics during new ball swing bowling. A 3D motion analysis system captured the bowling action and ball trajectory of 11 pre-elite and elite fast bowlers delivering outswing. Kinematics were normalised to 100% of the delivery stride between back foot contact and ball release. A statistical parametric mapping approach using one-way ANOVAs investigated inter-individual movement variability. Significant differences were found in all kinematic parameters except for wrist radial/ulnar deviation angular velocity with bowlers using small amounts in either direction at the beginning of the phase. This study highlights that high-level athletic performance can be achieved using different movement variations and future research should include individual analyses of fast bowlers.

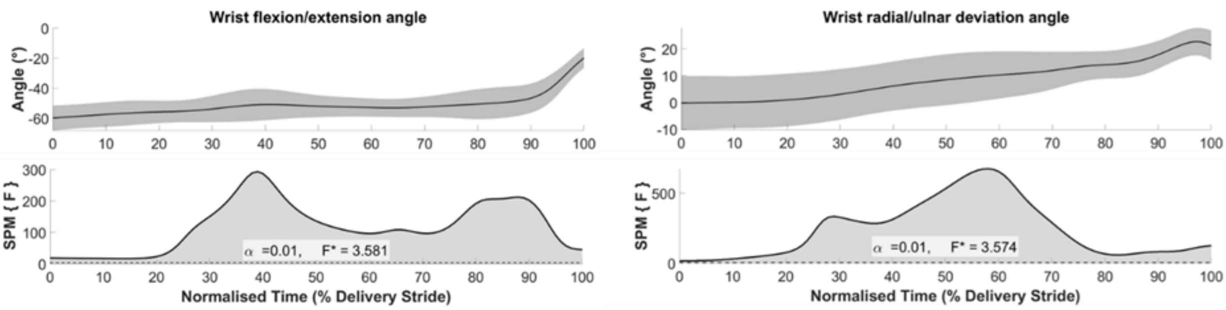
KEYWORDS: sport, swing bowling, technique variability, performance.

INTRODUCTION: In cricket, bowlers can restrict run scoring and claim wickets of opposition batters with swing bowling, a tactic used to make the ball deviate horizontally through the air as it travels towards the batter. Athletes use a bowling action that controls how the ball travels through the air, where the speed, seam orientation and spin imparted on the ball at release influences airflow around the ball to cause swing. Releasing the ball with an upright and angled seam and enough backspin to maintain this position is crucial to successfully create new ball conventional swing (Mehta, 1985). Swing bowling technique has only been investigated in regional Australian fast bowlers with athletes using their forearm and hand orientation to create the desired seam angle and wrist flexion to impart backspin on the ball (Lindsay & Spratford, 2020). Despite these findings, the techniques used by higher-level athletes remain unclear. A systematic review investigating other sporting movements in high-level athletes revealed elbow and wrist kinematics can be manipulated to alter the spin axis imparted on the ball (Lindsay et al., 2022). As swing bowling requires optimal ball flight characteristics (such as seam orientation, velocity, and spin rate), bowlers may employ similar strategies at the elbow and wrist. Understanding the movement variations used by fast bowlers to produce swing will help to inform training strategies to improve performance.

Inter-individual movement variability has been reported within scientific literature (Preatoni et al., 2013), however, research investigating individualised techniques in fast bowlers is lacking. Individual differences in anthropometry, joint mobility, and muscular strength influence how athletes complete sporting movements (Salter et al., 2007). Inter-individual movement variations have been reported in spinal kinematics of fast bowlers (Perrett et al., 2020) and differences in other parts of the body likely exist. To accurately inform swing bowling training strategies, research is required to investigate fast bowling technique variations. Therefore, this study investigated between-bowler variations in wrist and elbow kinematics during the delivery stride of fast bowlers delivering outswing. We hypothesised that significant differences would be found throughout the delivery stride, indicating that bowlers employ different techniques.

METHODS: Eleven Australian male pre-elite (state u19, n = 2) and elite (international u19 and senior state, n = 9) fast bowlers (age 19.9 ± 2.2 years, mass = 85.0 ± 10.2 kg, height = 191.8 ± 4.5 cm) participated in this study. The University of Canberra ethics committee approved this study and informed consent was provided by participants. Forty-eight retro-reflective markers were attached to the shoulders (Campbell et al., 2009), arms (Chin et al., 2010; Lloyd et al., 2000; Wells et al., 2018), thorax and head of participants according to the University of Western Australia upper-body model. Additionally, three retro-reflective tape patches, with a thickness of 0.1 mm to minimise aerodynamic interference, were placed on the sides of new Kookaburra Turf cricket balls (Sakurai et al., 2013; Whiteside et al., 2013). Data collection occurred at an indoor training facility with artificial wickets. Participants attended one testing session and used one new ball. They bowled a total of 18 deliveries consisting of nine inswing and nine outswing deliveries. All bowlers were right-handed and were asked to deliver the ball on a good-to-full length as though bowling to a right-handed batter at match intensity. A 40-camera Vicon motion analysis system (Oxford Metrics Ltd., Oxford, UK) sampling at 250 Hz captured marker trajectories during the delivery stride of the bowling action and the entirety of ball flight.
Vicon Nexus software was used to reconstruct and label marker trajectories. To calculate delivery swing, two vectors were created using the *x*,*y* coordinates of the ball at release, one frame post-release and at ball pitch (Lindsay & Spratford, 2020). For this study, outswing deliveries were analysed, and inswing deliveries were excluded from the dataset. Deliveries that swung less than 0.2°, and those where ball pitch coordinates could not be determined were excluded. On average, 7.2 ± 2.1 (range = 4 – 9) deliveries were included for each participant. Following a residual analysis, a fourth-order zero-lag Butterworth filter with a cut-off frequency of 14 Hz filtered upper-body marker trajectories. This data was then modelled using the valid and reliable University of Western Australia upper-body model to calculate joint kinematics. A cubic spline custom MATLAB program (Mathworks Inc; Natick, MA) extracted and normalised joint kinematics to 100% (101 points) of the delivery stride between back foot contact and ball release. The kinematic variables investigated included wrist flexion/extension, wrist radial/ulnar deviation, and elbow supination/pronation angles and angular velocities. Zero degrees represents a neutral alignment and positive angles represent wrist flexion, wrist ulnar deviation and elbow supination. Additionally, before each delivery, the ball grip angle was measured with a protractor using the primary seam relative to the index and middle fingers. Zero degrees represents a primary seam parallel to the fingers and a positive angle represents a seam position angled towards the left in relation to the bowler’s direction of travel.
MATLAB R2021b (The MathWorks, Inc., Massachusetts, USA) was used for data analysis. Participant means were used to calculate group means, standard deviations, and minimum and maximum values for ball grip and delivery swing. One-way ANOVAs using statistical parametric mapping (SPM) assessed between-bowler variability of wrist and elbow time-series data using individual participant trials. This method has previously been used to establish inter-athlete movement variability (Kristiansen et al., 2019). Significance was set at $p \le 0.01$.

RESULTS: The mean swing angle of the deliveries was 0.69 ± 0.30° (range = 0.3° – 1.3°) and the mean ball grip angle was 6.5 ± 10.0° (range = -29.9° – 5.8°). The SPM analysis revealed significant ($p \le 0.01$) inter-individual differences in all variables throughout the delivery stride (Figure 1). The only instance where significance was not reached was at the beginning of the delivery stride for wrist radial/ulnar deviation angular velocity.



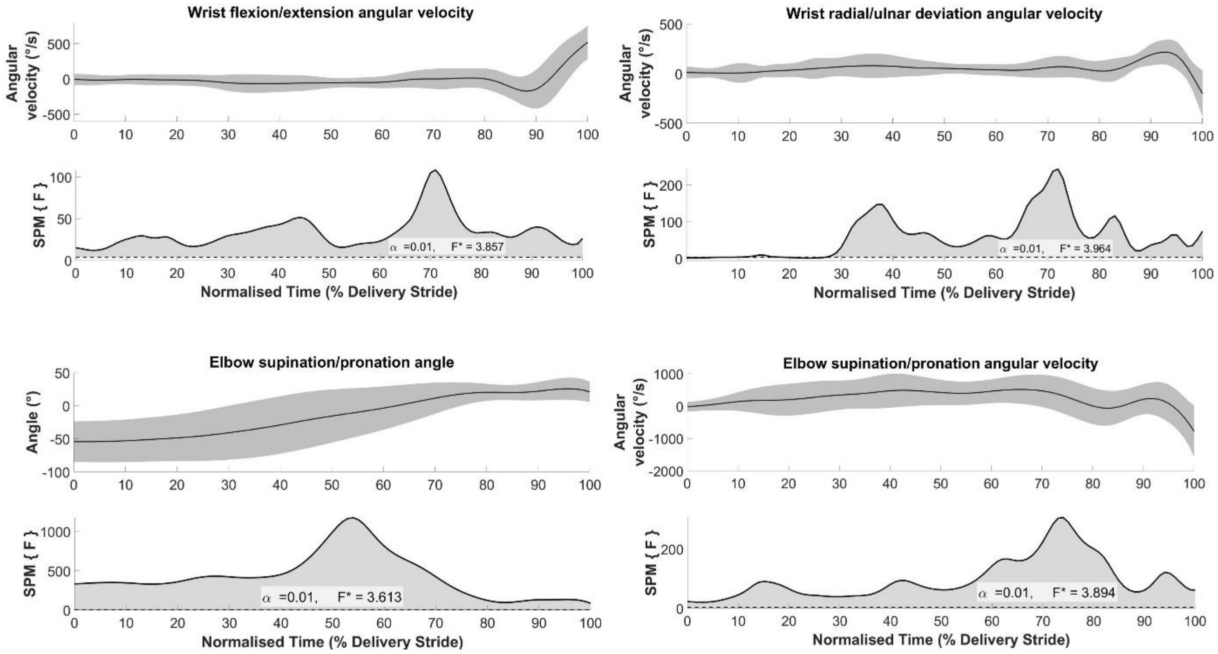


Figure 1. Results of the SPM and mean ± SD for wrist and elbow kinematics during the delivery stride. In the angle and angular velocity plots, the solid black lines represent the mean, and the shaded grey area represents the standard deviation. In the SPM plots, the horizontal black dotted line represents the critical F-value threshold and the grey area under the solid black line represents portions of the movement where significant differences occur between participants.

DISCUSSION: The current study found significant movement variability of wrist and elbow kinematics between fast bowlers delivering outswing with new cricket balls. The results indicate that bowlers use individualised techniques and is consistent with differences reported in a similar overhead movement in elite javelin throwers, suggesting high-level performance can be achieved using different movement variations (Campos et al., 2004; Kristiansen et al., 2019). Wrist radial/ulnar deviation angular velocity was the only variable where significant differences were not found in the early phase (approximately 30%) of the delivery stride (Figure 1). We hypothesise that athletes minimise lateral arm and wrist movements as the bowling arm begins to rotate. Following this, individualised movements are employed to position the hand and fingers to release the ball with an angled and upright seam (Lindsay & Spratford, 2020), as indicated by the high F-statistic values in the second half of the phase (Figure 1). The measured ball grip had high variability (range = -29.9° – 5.8°) which is another factor that must be considered. Bowlers likely use individualised grips, allowing them to produce the desired seam orientation required for swing bowling based on the position of their body at release.

Although the participants of this study had differences in skill and playing level, we believe these do not explain the magnitude of variability that was found. Human movement can be influenced by factors such as anthropometry, joint mobility, and muscular strength (Salter et al., 2007). Cricket researchers have also identified within-bowler variation with athletes using functional movement variability to adjust their technique to consistently achieve outcome goals (Phillips et al., 2012). This contributes to between bowler variation as athletes develop individualised motor solutions to achieve the same outcome goal (Vantorre et al., 2014). Generalising group results to individuals can be misleading (Fisher et al., 2018), particularly in sports biomechanics where athletes use highly individualised techniques to perform at an elite level. Future biomechanical investigations of sports movements should conduct individual analyses to best inform training strategies.

A limitation of the current study was that no post-hoc analysis was conducted to identify where individual differences occurred between bowlers. Additionally, this research investigated wrist and elbow kinematics only, whereas fast bowling is a complex whole-body movement requiring high levels of coordination with numerous body segments simultaneously moving throughout the bowling action. Future research should investigate whole-body kinematics and conduct individual analyses to understand the different techniques used by fast bowlers.

CONCLUSION: Time-series data of wrist and elbow kinematics of fast bowlers delivering outswing were found to vary significantly throughout the delivery stride, confirming the hypothesis that bowlers employ individualised movement strategies. While this study only investigated the elbow and wrist, whole-body movements are likely unique to each bowler. Generalising group results to individuals should be avoided and the movement variability of athletes should be considered by researchers and coaches. In practice, coaches should make individualised technique adjustments to enhance athlete performance. Future research should include individual analyses to understand movement variability and inform training strategies.

REFERENCES

Campbell, A., Lloyd, D. G., 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.

Campos, J., Brizuela, G., & Ramón, V. (2004). Three-dimensional kinematic analysis of elite javelin throwers at the 1999 IAAF World Championships in Athletics. *New Studies in Athletics*, *19*(21), 47-57.

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.

Fisher, A. J., Medaglia, J. D., & Jeronimus, B. F. (2018). Lack of group-to-individual generalizability is a threat to human subjects research. *Proceedings of the National Academy of Sciences*, *115*(27), E6106-E6115.

Kristiansen, M., Rasmussen, G. H., Sloth, M. E., & Voigt, M. (2019). Inter-and intra-individual variability in the kinematics of the back squat. *Human Movement Science*, *67*, 102510.

Lindsay, C., Clark, B., Middleton, K., Crowther, R., & Spratford, W. (2022). How do athletes cause ball flight path deviation in high-performance interceptive ball sports? A systematic review. *International Journal of Sports Science & Coaching*, *17*(3), 683-698.

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.

Lloyd, D. G., 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.

Mehta, R. D. (1985). Aerodynamics of sports balls. *Annual Review of Fluid Mechanics*, *17*(1), 151-189.

Perrett, C., Bussey, M. D., & Lamb, P. F. (2020). MOVEMENT VARIABILITY IN THE SPINAL KINEMATICS OF FAST BOWLERS. *ISBS Proceedings Archive*, *38*(1), 284.

Phillips, E., Portus, M., Davids, K., & Renshaw, I. (2012). Performance accuracy and functional variability in elite and developing fast bowlers. *Journal of Science and Medicine in Sport*, 15(2), 182-188.

Preatoni, E., Hamill, J., Harrison, A. J., Hayes, K., Van Emmerik, R. E., Wilson, C., & Rodano, R. (2013). Movement variability and skills monitoring in sports. *Sports Biomechanics*, *12*(2), 69-92.

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.

Salter, C. W., Sinclair, P. J., & Portus, M. R. (2007). The associations between fast bowling technique and ball release speed: A pilot study of the within-bowler and between-bowler approaches. *Journal of Sports Sciences*, *25*(11), 1279-1285.

Vantorre, J., Chollet, D., & Seifert, L. (2014). Biomechanical analysis of the swim-start: a review. *Journal of Sports Science & Medicine*, *13*(2), 223-231.

Wells, D. J., Donnelly, C. J., Elliott, B. C., Middleton, K. J., & Alderson, J. A. (2018). The inter-tester repeatability of a model for analysing elbow flexion-extension during overhead sporting movements. *Medical & Biological Engineering & Computing*, *56*(10), 1853-1860.

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.

Acknowledgements: The authors would like to thank Cricket Australia for supporting this project.