ELITE FEMALE CRICKET POWER-HITTING BATTING TECHNIQUE DIFFERS BETWEEN FAST AND SPIN BOWLING DELIVERIES

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The purpose of this study was to determine if elite female cricket batters' body or bat kinematics differed when facing fast or spin bowling in a power-hitting task. Six elite female cricket batters completed a straight drive power hitting task against both fast and spin bowling, captured by a 3D motion capture system. Select kinematic variables were analysed using Visual 3D software. Elite female batters may use the increased movement time afforded by the slower spin bowling speed to enhance bat-ball impact, bat speed and launch angle through reducing distance from the pitch of the ball to impact, and increasing thorax-pelvis separation (X-Factor) and top wrist ulnar deviation compared with facing fast bowling.

KEYWORDS: kinematics, range hitting, batters.

INTRODUCTION: Team success in twenty-over cricket (T20) is associated with batters scoring at a high run rate (Irvine and Kennedy, 2017). Therefore, understanding the technique characteristics of power-hitting, which translates to successful six-hitting (where the ball clears the boundary without touching the playing area), is desirable. Previous research has explored relationships between body kinematics and bat speed, a key predictor of carry distance, in male club to elite batters performing front-foot straight drives against fast bowling for maximum carry distance. This demonstrated that 78% of the observed variation in maximum bat speed is explained by: separation between transverse plane pelvis and thorax segments (X-Factor) at the top of the downswing, and top elbow extension and wrist ulnar deviation during the downswing (Peploe et al., 2019). However, there may be female specific power-hitting movement patterns (McErlain-Naylor et al., 2021). Compared with male batters, female batters face: slower fast bowling speeds, have smaller boundaries (Men: 59 – 82 metres; Women: 55 – 64 metres (ICC, 2021)), and are more likely to face spin bowling (% spin bowling in the last three T20 World Cups. Women: 57%; Men: 42%). Spin bowlers use: slower ball velocities, impart high spin rates on the ball, and alter flight trajectory, to deceive batters. Due these differences compared with fast bowling, there may be differences in batting kinematics between bowling types. Therefore the aim of this study was to determine if there are difference in body or bat kinematics against fast and spin bowling in elite female cricket batters.

METHODOLOGY: Six elite female cricket batters participated in this study (Mean ± SD. Age: 28.9 ± 2.9 years; Height: 1.70 ± 6.27 m; Mass 68.5 ± 3.2 kg; International T20 caps: 62 ± 36; International T20 Batting Average: 20.5 ± 5.5; International T20 Strike Rate: 110 ± 9). All participants provided written informed consent and health screen questionnaire prior to commencement of the study, and were declared injury-free by a physiotherapist. The study was approved by the Loughborough University ethics committee. Testing was conducted in an indoor cricket specific facility, on a full-sized artificial cricket pitch. Kinematic data were recorded using an 18-camera Vicon Motion Analysis System (OMG Plc, Oxford UK) operating at 250 Hz. All participants completed a self-selected warm-up and a series of familiarization trials of the power-hitting task under equivalent testing conditions immediately before data collection. Forty-six retro-reflective markers were attached to each participant according to previous methodologies, as well as four markers positioned on the four corners of the rear side of the bat. Five 15 x 15 mm pieces of reflective tape was placed on the ball (Peploe et al. 2019). Each participant faced 19 ± 3 deliveries of seam and spin against two bowling machines (Fast bowling: BOLA Professional; Bristol, UK; Release speed: 29.1 m/s; Spin Bowling: Merlyn by BOLA; Bristol, UK; Release speed 20.1 m/s) aimed at a good to full length. Participants

were instructed to hit the ball straight (towards the bowler) for maximum carry-distance. Ball release speeds were selected by an international coach. Use of each participant's own bat avoided any effect of unfamiliar bat inertial properties on shot kinematics.
All markers were labelled within Vicon Nexus software (Version 2.11, OMG Plc, Oxford, UK). Trajectories were filtered using a recursive two-way Butterworth low-pass filter with a cut-off frequency of 15 Hz, determined via residual analysis (Winter, 1990). Whole body kinematics were defined and processed according to Peploe et al. (2019). Local coordinate systems were defined in Visual 3D (C-Motion Inc., Germantown, USA). Joint centres were defined as the mid-point of a pair of markers positioned across the joint, except for the hip (Bell et al., 1989) and thorax (Worthington et al., 2013). Joint angles were calculated as Cardan angles using an xyz sequences, corresponding to flexion-extension, abduction-adduction, and longitudinal rotation, respectively. Pelvis and thorax rotations were calculated relative to the global coordinate system using a zyx Cardan sequence (Baker, 2001). Whole-body centre of mass was computed from segment geometry and relative masses (Hanavan, 1964). A logarithmic curve fitting methodology previous used in studies of cricket power-hitting was used to determine resultant instantaneous post-impact ball speed and vertical ball launch angle for each trial (Peploe et al., 2018). A validated iterative ball flight model was used to determine ball carry distance (Peploe, 2016).
The best trial for each participant (greatest ball carry distance) was identified for each condition and used for analysis. Kinematic data previously associated with cricket straight drive power-hitting performance were extracted for analysis (Peploe et al. 2019). This included X-Factor (positive value indicates greater thorax rotation towards the dominant batting hand side relative to the pelvis), radial/ulnar deviation of the top wrist (>180° = radial deviation) and flexion/extension of the top elbow (<180° = flexion). This data were extracted from key instances including: top of downswing, bat-ball impact and maximum and minimum angle. In addition, whole body centre of mass was determined as its position at impact relative to during the stance (ready position before the ball is released) in the global Y-axis direction (towards the bowler is positive). The duration of the downswing was also determined. Finally, bat kinematics including the bat centre of mass height at the top of the downswing, bat angle about the global X-axis (medio-lateral) at both top of downswing and impact (negative value indicates the bat is behind the vertical plane), and the maximum bat velocity during the downswing. Statistical analyses were performed in SPSS (V.27, IBM, USA). Following assessment of normality, paired sample t-tests (Wilcoxon signed-rank test if non-parametric) were used for each variable to determine differences between the fast and spin bowling conditions. An Alpha level of 0.05 was used for all tests.

RESULTS: When batting against spin, participants achieved significantly greater carry distance. The vertical launch angle was also close to being significantly greater compared with batting against fast bowling (Table 1). No further significant differences were observed in bat or ball variables between groups.

Table 1: Mean ± SD bat and ball variables between fast and spin deliveries

	Delivery Type			
Variable	**Fast**	**Spin**	**Mean Difference**	***p***
Carry Distance (m)	66.8 ± 5.9	71.4 ± 5.8	-4.6 ± 2.9[c]	0.023
Post-Impact Ball Velocity (m/s)	30.3 ± 1.72	30.9 ± 1.37	-0.6 ± 1.1[a]	0.336
Impact Height (m)	0.62 ± 0.13	0.61 ± 0.05	0.01 ± 0.10	0.862
Launch Angle (°)	34 ± 3	39 ± 3 4	-6 ± 4[c]	0.051
Bat COM Height: Top of DS (m)	1.25 ± 0.10	1.23 ± 0.07	0.02 ± 0.06[a]	0.449
Maximum Bat Velocity (m/s)	23.5 ± 2.9	24.4 ± 1.8	-0.8 ± 1.6[b]	0.250
Bat Angle (X): Top of DS (°)	-171 ± 20	-173 ± 23	2 ± 8[a]	0.545
Bat Angle (X): IMP (°)	20 ± 10	29 ± 7	-9 ± 14[b]	0.172

[a] Denotes small effect size. [b] Denotes medium effect size. [c] Denotes large effect size. DS: Downswing. IMP: Impact

When batting against spin bowling, participants demonstrated significantly less top wrist radial deviation at impact, significantly greater ulnar deviation between maximum radial deviation and impact and had significantly greater whole body centre of mass anterior displacement towards the bowler between stance and impact, compared with when batting against fast bowling (Table 2). The X-Factor separation between the top of the downswing the maximum value was also close to being significantly greater when facing spin bowling compared with fast bowling. No other differences were observed for any other values of wrist, elbow or X-factor kinematics, or downswing duration.

Table 2: Mean ± SD (Median (IQR) for non-parametric data) joint angles (°), whole body centre of mass (COM) displacement and downswing duration between fast and spin deliveries

		Delivery Type			
Variable	**Timing**	**Fast**	**Spin**	**Mean Difference**	***p***
Top Wrist Angle (Y-axis)	Top of DS †	243 (239, 246)	242 (231, 244)	2 ± 6[a]	0.438
	Max	256 (249, 267)	262 (255, 264)	-3 ± 7[a]	0.438
	IMP	201 ± 10	189 ± 11	12 ± 8[c]	0.016
	Top of DS to Max	15 ± 9	20 ± 9	-5 ± 13[a]	0.356
	Max to IMP	-52 ± 18	-67 ± 20	-15 ± 7[c]	0.004
Top Elbow Angle (X-axis)	Top of DS	120 ± 20	118 ± 20	2 ± 5[a]	0.289
	Min	121 ± 20	120 ± 20	2 ± 15	0.792
	IMP	131 ± 19	130 ± 22	1 ± 13	0.887
	Top of DS to Min	0 ± 27	1 ± 27	1 ± 13	0.925
	Min to IMP	10 ± 7	11 ± 9	1 ± 9	0.794
X-Factor (transverse plane pelvis-thorax separation)	Top of DS †	20 (20, 23)	17 (12, 18)	3 ± 7[b]	0.219
	Max	27 ± 7	29 ± 5	-2 ± 7[a]	0.597
	IMP	-7 ± 7	-6 ±9	0 ± 8	0.974
	Top of DS to Max	8 ± 6	14 ± 9	-6 ± 7[c]	0.086
	Max to IMP	-34 ± 10	-35 ± 7	-2 ± 4[a]	0.404
COM Displacement (m)	Stance to IMP	0.35 ± 0.12	1.17 ± 0.19	-0.82 ± 0.26[c]	0.001
DS Duration (s)	-	0.21 ± 0.03	0.22 ± 0.03	-0.01 ± 0.02[b]	0.256

[a] Denotes small effect size. [b] Denotes medium effect size. [c] Denotes large effect size. † Denotes non-parametric. DS: Downswing. IMP: Impact

DISCUSSION: This is the first study to explore differences in cricket batting kinematics between fast and spin bowling and demonstrated between group differences in carry distance, launch angle, whole body centre of mass displacement, top wrist angles and X-Factor. Large differences were observed between conditions in centre of mass displacement, where in the spin condition batters intercepted the ball 1.17m away from their stance, compared with 0.35m in the fast bowling condition (Table 2). This is likely a consequence of the slower bowling speed, allowing the batter time to respond to the trajectory of the incoming ball. By getting closer to the pitch (bounce) of the ball, they reduce the risk of being deceived by unexpected vertical or lateral movements, increasing their chances of achieving a bat-ball impact which is closer to the sweet-spot, enhancing carry distance. In addition, this approach generates linear momentum, which may contribute to bat speed through transfer of energy to distal segments and ultimately the bat.

There are also differences in X-Factor angles between bowling types, which is the greatest kinematic predictor of bat speed in male batters (Peploe et al. 2019). Increased X-Factor likely results in greater utilisation of the stretch shortening cycle, where the powerful muscles of the upper torso eccentrically stretch, and then rapidly release their elastic energy during the concentric phase (X-Factor reversal), increasing total muscular force and power (Komi, 1984). This increased energy may be utilised by rotations of more distal segments through the conservation of angular momentum, potentially contributing to increased bat velocity. When

facing spin, there is a greater change in X-Factor angle between the top of the downswing and maximal value compared with facing fast bowling, by 6 degrees, which may compensate for the lower separation observed in spin bowling at the top of the downswing compared with batting (Table 2). Further it may suggest there is a difference in timing of maximum X-Factor or in X-Factor angular velocities between the two bowling modalities. Coupled with the similar downswing time between conditions, it may suggest that when facing spin, batters more efficiently utilise the stretch shortening cycle, through a more rapid stretching of the upper torso musculature. Coupled with the increased linear momentum when facing spin, it may decrease the demands placed on more distal joints to contribute to bat speed. This may explain why there is great variation in elbow kinematics between conditions (Table 2) and between female batters (McErlain-Naylor et al. 2021), where a trade-off may exist between elbow angle contribution to bat speed and to impact location.
Finally, when facing spin, batters demonstrated significantly less radial deviation at impact which is likely caused by the increased ulnar deviation between maximum radial deviation and impact compared with when facing fast bowling (Table 2). Increased ulnar deviation between maximum radial deviation and impact has previously been associated with increased bat speed and therefore carry distance (Peploe et al. 2019), however bat speed was the same between conditions in the current study (Table 1). Less radial deviation at impact may be associated with an increased bat angle at impact, which likely results in an increased vertical launch angle (Peploe et al. 2019). Vertical launch angles were 5 degrees greater in the spin condition compared with the fast condition, and were close to the optimum launch angle for cricket balls suggested by Peploe (2016, 39° v 42°) which likely contributed to the increased carry distance observed in the spin condition. Against fast bowling, batters may not have enough time to get their top wrist in a more ulnar deviated position to optimise launch angle.

CONCLUSION: Elite female batters use different techniques when facing spin and fast bowling. Against spin, batters may use the increased movement time afforded by the slower spin bowling speed to enhance bat-ball impact, bat speed and launch angles through decreasing distance between pitch of the ball to impact, and increasing pelvis-thorax separation (X-Factor) and top wrist ulnar deviation compared with facing fast bowling. Future research should explore optimal sex-specific power-hitting technique against bowling of different trajectories and velocities.

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