RELATIONSHIPS BETWEEN HITTING TECHNIQUE AND BALL CARRY DISTANCE IN CRICKET

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The aim of this study was to identify the technique parameters characterising batsmen who generate large carry distances, ball launch speeds, and bat speeds during a range hitting task in cricket. Kinematic data were collected for 20 batsmen, and a series of ball launch, impact, and technique parameters were calculated for each trial. A regression analysis found impact location relative to the sweetspot and bat speed together to explain 70% of the observed variation in ball speed. A further regression analysis found the maximum X-factor (the separation between the pelvis and thorax segments in the transverse plane), front elbow extension, and wrist uncocking during the downswing explained 66% of the observed variation in bat speed. These findings will be useful in coaching more effective hitters, and in assessing the mechanics of generating bat speed.

KEY WORDS: velocity, bat speed, X-factor, linear regression, impact location, ball speed

INTRODUCTION: The ability of batsmen to clear the boundary is a major contributor to batting success in the modern game (Petersen et al., 2008). To date there have been no studies investigating the technical aspects of range hitting in cricket, with the majority of research focused on establishing the mechanics of the front foot drive (Stretch et al., 1998; Stuelcken et al., 2005), or identifying differences in technique displayed by batsmen when facing different delivery methods (Pinder et al., 2011; Peploe et al., 2014).

Despite the lack of research in cricket, a number of studies have investigated the technical factors important to the generation of clubhead and bat speed in golf and baseball. In golf, a large angular separation between the pelvis and upper thorax in the transverse plane (often referred to as the X-factor; Mclean, 1992) at the top of the backswing and during the downswing, has been strongly linked to increased clubhead speed (Cheetham et al., 2001; Chu et al., 2010). In baseball, Welch et al. (1995) found professional baseball hitters to exhibit front knee extension in the approach to impact, pushing the front hip backwards and acting as a block around which the body can powerfully rotate, thus generating high bat speeds. Similarly, an increased cocking and uncocking of the wrists, and extension of the lead elbow has been found to significantly increase golf clubhead and baseball bat speed (Robinson, 1994; Welch et al., 1995; Escamilla et al., 2009; Chu et al., 2010).

The purpose of this study was to identify the parameters and techniques characterising those batsmen able to generate large carry distances, ball launch speeds, and bat speeds during a range hitting task in cricket. As the carry distance is fundamentally a function of ball speed and vertical launch angle, further investigation of these primary outcome measures will allow a greater understanding of the mechanisms and techniques related to success in range hitting. This will provide valuable information to players and coaches in the development of more effective hitting techniques, and form a basis for the continued assessment of the mechanics of generating ball and bat speed in cricket batting.

METHODS: Twenty male cricket batsmen (age 22.5 ± 3.1 years (mean ± SD), height 1.82 ± 0.04 m, mass 80.0 ± 7.8 kg) performed a series of shots (14 ± 4) against a bowling machine (BOLA Professional), aiming to hit the ball straight back over the bowler's head for six. Participants included one England batsman, two from the England Lions squad, nine county cricketers including six who had represented England under 19's, and eight club batsmen. Testing procedures were explained to each participant and informed consent was obtained in accordance with the Loughborough University Ethical Advisory Committee. The bowling machine was directed towards a full length suitable for the shot as directed by the batsman, arriving with a pre-impact speed of 25.0 ± 1.3 ms^{-1}. Only trials where the ball was projected forwards in the anterior-posterior plane (towards the bowler) post-impact were selected for analysis (n = 239; 12 ± 2 trials per subject).

Kinematic data were recorded at the England & Wales Cricket Board (ECB) National Cricket Performance Centre using an 18 camera Vicon Motion Analysis System (OMG Plc, Oxford, UK) operating at 250 Hz. Synchronous high-speed video (250 Hz) captured the timing of ball release. Forty-six 14 mm spherical reflective markers were attached to each batsman, positioned on, or on padding adjacent to, bony landmarks. An additional four markers were positioned on the blade of the bat, and five 15 x 15 mm squares of reflective tape were placed on the ball. Batting trials were labelled within Vicon Nexus software, and trajectories were filtered using a recursive two-way Butterworth low-pass filter with a cut-off frequency of 15 Hz. Local coordinate systems were defined in Visual 3D software (C-Motion Inc., Germantown, MD, USA), forming a three-dimensional 14 segment model of a batsman. Events corresponding to the commencement of the downswing (DS) and the time of bat-ball impact (IMP) were identified from the kinematic data (Peploe et al., 2014).

For each trial the impact location from the sweetpot (17.5 cm from the toe along the midline of the bat) in the X (medio-lateral) and Z (longitudinal) directions on the bat, resultant post-impact ball speed, and vertical ball launch angle were determined using the single ball displacement equation of Peploe (2016). Ball carry distance was calculated using an iterative ball flight model accounting for gravity and air resistance developed for this study. The maximum pre-impact resultant bat distal endpoint speed during the downswing was calculated from the kinematic data. Twenty-five further kinematic parameters determined from acedmic and coaching literature were also calculated for each trial, describing elements of technique that have been linked to increases in clubhead or bat speed in other hitting sports, or that are thought to be important by elite coaches: bat angle at DS and IMP; bat angular rotation (DS to IMP); wrist cocking angle at DS and IMP; minimum wrist cocking angle (DS to IMP); wrist uncocking (DS to IMP); bat centre of mass (COM) height at DS; front and back elbow angles at DS and IMP; front and back elbow extension (DS to IMP); X-factor and X'-factor at DS and IMP; maximum X-factor and X'-factor (DS to IMP); X-factor and X'-factor reduction (DS to IMP); whole-body COM displacement Y (ball release to IMP); downswing duration; and base length at IMP.

Bat angle was calculated as the angular rotation of the bat about the global medio-lateral axis (corresponding to the main axis of rotation during the swing). The wrist cocking angle was calculated as the angular offset between the forearm of the front arm (left arm for right-handed batsmen) and the bat, corresponding to abduction/adduction at the wrist joint. Bat COM height was calculated as the height of the bat COM (determined from measurements taken during data collection) in the global vertical plane. Angles describing the front and back elbows (straight = 180°, flexed = < 180°) corresponded to the anatomical flexion/extension angle of the joint. X-factor and X'-factor were calculated as the angular separation between the pelvis and thorax segments in the transverse and frontal planes respectively. The whole-body COM was computed in Visual 3D software from the segment geometry and mass relative to the whole body. The displacement of the whole-body COM was calculated as the difference between the COM position at ball release and impact in the global anterior-posterior (Y) plane. Downswing duration was determined as the time interval between DS and IMP. Base length was calculated as the resultant distance between the COM of the left and right feet at IMP.

All statistical analyses were performed within SPSS v.23 (IBM Corporation, Armonk, NY, USA). Initially a forward stepwise multiple linear regression was conducted to explain the variation in ball launch speed. The three best trials in terms of ball launch speed were then identified for each subject, and averaged for each parameter to provide representative data for each batsman (Worthington et al., 2013). The effect of these technique variables on bat speed was assessed using a further forward stepwise linear regression with a maximum of four variables included in the predictive equation. The requirement for the inclusion of a variable in the regression equations was $P < .05$, with a subsequent removal level of $P > .10$.

RESULTS AND DISCUSSION: The 239 trials selected for analysis had a substantial range of carry distances of 3.5 – 103.5 m (mean ± SD: 52.2 ± 19.6 m) and a wide range of launch parameters (Table 1). Although the range of vertical launch angles observed in this study was large, players generated launch angles on average (37.5°) below the optimum (42° according to the flight model), perhaps favouring lower trajectories to minimise the risk of launching the ball too high and thus giving fielders time to reposition for a catch.

Table 1
Range, mean, and standard deviation of the launch parameters.

Variable	Range	Mean ± SD
Vertical ball launch angle (°)	0.6 – 89.5	37.5 ± 20.4
Ball launch speed (ms^{-1})	17.8 – 39.5	28.1 ± 4.2
Max. distal bat endpoint speed (ms^{-1})	17.2 – 30.9	25.7 ± 1.96

The best individual predictor of ball launch speed was the distance of ball impact from the estimated sweetspot of the bat in the medio-lateral plane (impact location X), explaining 27.8% of the variation in ball launch speed. The inclusion of the bat speed and impact location Y parameters increased the total explained variation in ball launch speed to 69.6% (SEE = 2.295 ms^{-1}; Table 2). Trials with an impact location nearer the estimated sweetspot in both the medio-lateral and longitudinal plane of the bat, and with a higher pre-impact bat speed, were found to produce a higher ball launch speed. The combined importance of impact location, together explaining 44.4% of the variation in ball launch speed, suggests that players who are consistently able to impact the ball close to the sweetspot of the bat are more likely to be successful than those who generate a higher bat speed without the required accuracy. However, for those players able to consistently generate impacts near the sweetspot, increasing bat speed on the approach to impact through training becomes vital in producing higher ball launch speeds.

Table 2
Regression equations for ball launch speed using forward stepwise linear regression.

Model	Parameter	Unstandardised B Coefficient	95% C.I.	p- value	Percentage explained
1	Impact location X	-105.56	-127.34 to -83.78	<0.001	27.5
2	Impact location X	-113.05	-130.68 to -95.42	<0.001	52.7
	Bat speed	1.07	-0.89 to 1.26	<0.001	
3	Impact location X	-108.76	-122.92 to -94.60	<0.001	69.6
	Bat speed	0.98	0.83 to 1.13	<0.001	
	Impact location Y	-40.08	-46.95 to -33.21	<0.001	
	Constant	8.43	4.50 to 12.36	<0.001	

The best individual kinematic predictor of bat speed was the maximum angular separation of the pelvis and thorax segments in the transverse plane during the downswing (max X-factor), explaining 38.4% of the variation in bat speed. Inclusion of the magnitude of front elbow extension (F elbow extension DS) and wrist uncocking (wrist uncocking DS) present during the downswing to the regression equation, increased the total explained variation in bat speed to 66.1% (SEE = 0.961 ms^{-1}; Table 3). Participants who displayed a larger maximum angular separation between the pelvis and thorax segments in the transverse plane, and a greater magnitude of front elbow extension and wrist uncocking during the downswing, were found to generate higher bat speeds. This supports findings in golf (Cheetham et al., 2001; Chu et al., 2010) and baseball (Robinson, 1994; Welch et al., 1995; Escamilla et al., 2009), where the X-factor, lead elbow extension, and wrist uncocking have all been found to be important in generating high clubhead/bat speeds during the downswing, and highlights three key areas for players and coaches to target during technical and strength and conditioning training.

Table 3
Regression equations for ball launch speed using forward stepwise linear regression.

Model	Parameter	Unstandardised B Coefficient	95% C.I.	p-value	Percentage explained
1	Max X-factor	0.156	0.065 to 0.248	<0.01	38.4
2	Max X-factor	0.148	0.066 to 0.230	<0.01	51.6
	F elbow extension DS	0.054	0.007 to 0.101	<0.05	
3	Max X-factor	0.134	0.065 to 0.204	<0.01	66.1
	F elbow extension DS	0.062	0.022 to 0.101	<0.01	
	Wrist uncocking DS	0.069	0.018 to 0.120	<0.05	
	Constant	17.622	14.484 to 20.761	<0.001	

CONCLUSION: This study has identified a series of parameters which explain the majority of the variation in ball launch speed and bat speed during a range hitting task. Impact locations near the sweetspot, along with high bat speed, are critical in generating high ball launch speeds. Analysis of technique variables revealed that the biggest hitters exhibit a greater maximum X-factor, as well as increased front elbow extension and wrist uncocking during the downswing. The results of this study are likely to be very useful in the coaching of range hitting to elite and developing batsmen, and in guiding the direction of future research in this area. Batsmen should initially focus on generating accurate timing and impact locations before attempting to increase bat speed. However, for the elite population studied here, monitoring and improving the key technical parameters in this study could provide substantial improvement in range hitting ability.

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