Lower Extremity Kinematics of the Successful and Unsuccessful Cricket Pull Shots of the Malaysian National Cricket Batsmen

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Muhammad Zia Ul Haq* | Muhammad Badar Habib† | Muhammad Tahir Nazeer‡

Abstract *This research is about the kinematics analysis of the lower extremity of the cricket batsmen at the attempt of successful and unsuccessful pull shots. Data were recorded from (n = 18) Malaysian cricket batsmen by using two video cameras. Repeated measures ANOVA was applied for statistical analysis. Results showed the back lift, angular movements of the knees, hips joints, velocities of the left knee, hip and bat were significantly faster at successful pull shot than unsuccessful shots. It was concluded the higher angular position of knees and hips joints increase the vertical position of batsmen to execute a successful pull shot. The cricket coaches are required to focus on the improvement of high backlift, a higher extension of knees and hips, faster movement left leg and bat the time of bat-ball impact. These kinematics of the lower extremities are a key point for the execution of successful pull shot in cricket.*

Key Words: Cricket Batting, Batsman, Short Pitch Ball, Bat Swing, Pull Shot

Introduction

The pull shot is a cricket shot that played against the short pitch ball (Kelly, Curtis, & Craven, 2003). A batsman executes the short pitch ball of a fast bowler by swinging his bat at a horizontal arc parallel to the shoulders (Land & McLeod, 2000). The pull shot is like chain movement which starts from the backswing of the bat, followed by the back foot stride across the off stump, downswing of the bat for bat-ball impact in front of the chest (Woolmer, Noakes, & Moffett, 2008; Cross, 2009). The downswing of bat occurs parallel to the shoulder (Cross, 2009), to strike the short pitch ball in front of the chest (Woolmer et al., 2008). An appropriate movement of the lower extremity maximizes the chances of a successful pull shot (Larry, 2013). The initial movement of the lower extremity generates a force that transmits into the ball through the trunk, upper limb and bat (Adair, 1995; Welch, Banks, Cook, & Draovitch, 1995; Lund & Heefner, 2005). Higher extension of knee and hip assist the batsmen to keep the trunk and shoulder in an upright position in front of the upcoming short pitch ball (Woolmer et al., 2008).

The back leg becomes the center of rotation (Bradman, 1958), an accurate position of feet increase batsman's balance (Fortenbaugh, 2011). The cricket experts are sure the flex and slower movement of the lower extremity would result as an unsuccessful pull shot (Bradman, 1958; Knight, 2007; Pyke & Davis, 2010; Woolmer et al., 2008). The cricket experts have explained various causes of the unsuccessful pull shot by using their personal experience. In contrast, the researcher has explained the perception and reaction time of batsmen while playing the short pitch ball (Land & McLeod, 2000; Headrick, Renshaw, Pinder, & David, 2012). A previous study has qualitatively explained the kinematics of the pull shot (Kelly et al., 2003). However, the underlying mechanics of lower extremity in performing pull shots are not well understood to the author's knowledge. There is no study which quantitatively analyzes the kinematics of lower extremity at successful and unsuccessful pull shot.

*Lecturer, Physical Education and Sport Science, The Islamica University of Bahawalpur, Bahawalpur, Punjab, Pakistan. Email: muhammad.zia@iub.edu.pk
† Lecturer, Physical Education and Sport Science, The Islamica University of Bahawalpur, Bahawalpur, Punjab, Pakistan.
‡ Assistant Professor, Department of Sport Science & Physical Education, The University of Punjab, Lahore, Punjab, Pakistan.

Therefore, this research was intended to analyze the kinematics of lower extremity at successful and unsuccessful pull shots. It was hypothesized, the kinematics of the successful and unsuccessful pull shot would have no significant difference.

Method and Material

Subjects

Data were obtained from (n = 18) Malaysian cricket batsmen. The selected batsmen were seniors age = 23.9 (4.2) years, height = 174.3 (5.9) cm, body mass = 72.9(5.8) kg, and junior age = 18.4 (3.5) years, height = 169.5 (6.7) cm, body mass = 65.10 (3.90) kg. The senior batsmen have represented the Malaysian national cricket team in international cricket matches. On the other hand, the junior batsmen who represent Malaysian junior, under-19 and under-16 cricket teams in international matches. The procedure of the study was briefed to all participants, and written consent was obtained to assure their volunteer participation. Data were compiled at the Kinrara Oval Cricket Stadium, Malaysia. This study was approved by the research committee of the Sultan Idris Education University, Malaysia.

Tools for Data collection

All participants performed a pull shot at the short pitch ball at the synthetic cricket pitch. The ball machine (BOLA, Stuart & Williams, UK) for bowling (Weissensteiner, Abernethy, & Farrow, 2011; Headrick et al., 2012). The video data was recorded with 02 video cameras (Sony, Tokyo, Japan) which operated at 60 Hz to record batting action (Renshaw, Oldman, David, & Gold, 2007). A twenty-four-points calibration frame was used for 3-d capturing of cricket batting. The volume of action was explained as three-meter at X-axis, one and a half meter at Y-axis and two meters at Z-axis for the transverse plane (Stuelcken, Portus, & Mason, 2005).

Marker Placement

Eight reflective markers (14mm) were placed at the lower body joints (Taliep, Galal, & Vaughn, 2007). All batsmen performed batting in protective equipment; therefore, few markers were adjusted at the helmet, leg pads, and shoes. 02 markers were positioned at the phalanges of the outer side of the right and left to and ankle, 02 markers over at the lateral femoral condyle, to find the movement knee joints. These markers were placed at the bottom and top of the pads (Renshaw et al., 2007). Another 02 pated at the right and left hip joint. More, 06 markers were pasted bat the handle and blade of cricket bat were also digitized to find the linear and angular kinematics of bat (Stuelcken et al., 2005). The head movement was tracked with a marker of a helmet.

The Procedure of Data Collection

Camera number one was placed 13 meters toward the front side of the batsman and number two toward to the bowling crease, with the lens height 1.4 meters from the ground surface. The ball projection machine was set with 17.68 meters distance from batting end the ball release point was 2.30 meters above the surface Fig. 1 (Renshaw, et al, 2007), and ball speed and bounce were controlled (Pinder et al., 2011). Each batsman participated in a warm-up session against the ball machine. Every ball was exposed to batsmen before delivering through the ball machine.

The 06 trail of the pull shots of a batsman was recorded and assessed by the certified cricket coaches to identify the successful and unsuccessful pull shots. The successful orthodox pull shots explained in coaching manuals suggest that the stroke is played at the full face of the bat, and toward the square leg of the ground (Woolmer et al., 2008). The unsuccessful pull shot was defined as the ball arise upward rather than crossing the boundary, which provides catching with the opportunity to the surrounding fielders (Pyke & Davis, 2010). The pull shot action was divided into three phases as the stance, the back lift of bat, and the bat-ball contact which help to understand the kinematics analysis in an easy way.

Data processing

The Ariel Performance Analysis Software (Ariel Dynamics Inc, USA) was utilized for analyzing the pull shot actions. The 1st and 2nd camera was synchronized to find a similar point of the pull shot. The videos of both

cameras were trimmed after finding a similar point of action. All selected videos were digitized with a stick figure. Eight joints markers were digitizing, four markers at the bat corner and two along with bat handle (Stuelcken et al., 2005). The bat-ball contact was determined by digitizing the ball. Two-dimensional coordination digitized data were transferred into 3-dimensional coordination by using the direct linear transformation (DLT) method (Abdel-Aziz & Karara, 1971). The cubic spline low filter pass was used to smooth the raw data (Escamilla, et al., 2009).

Stride length was considered as the toe-to-toe distance of the front and back foot at the X-axis. The height of the bat and center of gravity of the batsmen have considered in a vertical position in the Y-axis direction. The speed of the bat was considered with the displacement of the bat in the direction X-axis. The angular kinematics of the joints was defined as 180°-degree and zero degrees based on the full extension and flexion of the joint (Inkster, Murphy, Bower, & Watsford, 2010). Knee angle was considered with the intersection of the ankle to knee and hip. The hip angle from knee to hips, and hips to the shoulder. The bat angle from the upper corner of the blade to the lower corner of the blade and lower corner to the vertical position direction of the ground surface as a vector.

The mean score of two successful and two unsuccessful pull shots was taken as the final score to reduce the variability of kinematic data (Mullineaux, 2007). With the interval of two months, the digitized videos were randomly re-digitized for testing the reliability. The coefficient of variance (CV) was implemented for inter-tester reliability such as in stride length 7.6%, bat height 5.4%, bat velocity 8.1%, left knee angle 4.1%, and hip velocity 7.6%. The range of reliability was 3.1 to 10.7mm for linear and 3.1 to 10.7° for the angular kinematics (Stuelcken et al., 2005).

Statistical Analysis

The mean and standard deviation of linear and angular kinematics were obtained. Repeated measure was ANOVAs was applied to compare the stride length, center of gravity, knee angle, hip angle, knee, and hip velocity, and bat velocity of 2 groups (senior, and junior batsmen) x 3 levels (stance, back lift, impact) x 2 conditions (successful vs unsuccessful shot). Assumptions, as data normality, homogeneity, and multicollinearity were tested without any serious violation (Pallant, 2007; Field, 2009). Tukey's post hoc was applied to find the source of difference when a significant main effect was found. The significant values were adjusted at ($P < .05$) for all variables.

Results

Results showed a significant main effect within-groups in the bat height at successful and unsuccessful pull shot at the back lift, $F = 9.97$, $P < .01$, $\eta p2.40$. Tukey post hoc showed that the bat height of senior batsmen was significantly higher at a successful pull shot than the unsuccessful. There were significant main effects between-groups at the bat height in the attempt of successful pull shots at impact, $F = 4.19$, $P < .03$, $\eta p2.39$. There were significant main effects within-groups in the head-ball distance at impact at successful and unsuccessful pull shot, $F = 9.13$, $P < .01$, $\eta p2.38$. Post hoc results showed the distance of the ball from the head at the impact of senior and junior batsmen was significantly longer at a successful shot than unsuccessful (Table 1).

Table 1. Kinematics Description of the Successful and Unsuccessful Pull Shots

	Senior batsmen		Junior batsmen				
	Successful	unsuccessful	Successful	unsuccessful	W-G	B-G	interaction
Measure	Mean±SD	Mean±SD	Mean±SD	Mean±SD	*P*	*P*	*P*
Stride time (s)	.23±.05	.25±.03	.24±.05	.25±.05	.14	.96	.67
Bat swing time (s)	.64±.11	.67±.09	.65±.09	.66±.09	.46	.35	.84
Stride length (m)	.78± .11	.82±.06	.82±.07	.84±.12	.30	.74	.48
Back lift height (m)	1.63±.03*	1.56±.05*	1.60±.11*	1.55±.13*	.01	.51	.52
Bat height at impact (m)	1.21±.06	1.20±.13	1.23±.09*	1.23±.09	.75	.03	.65
COG height at back lift (m)	.94±.07	.96±.05	1.0±.07	1.00±.04	.40	.26	.68

COG height at impact (m)	1.02±.06	1.01±.06	1.07±.07	1.05±.05	.08	.14	.91
Head-ball at impact (m)	.85±.10*	.77±.15*	.88±.06*	.73±.15*	.01	.93	.75

**The level of significance adjusted at P .05.* W-G (within the group), B-G (between groups), interaction (groups and pull shots)

The angular kinematics showed significant main effect within-groups at the left hip angle at impact, F = 13.75, P< .00, ηp2. .478, and significant main effect between-groups, F = 5.12, P <.02, ηp2 .41. The hip angle of senior batsmen was significantly higher at a successful pull shot than unsuccessful. There were significant main effects within-groups at the right hip angle at successful and unsuccessful pull shot at impact, F = 8.10, P <.01, ηp2.35. Tukey post hoc showed the right hip of senior batsmen were significantly more extended at a successful pull shot than unsuccessful. There were significant main effects within-groups in the bat angle at successful and unsuccessful pull shot at impact, F = 5.69, P <.03 ηp2.28. The senior batsmen had a significantly lesser bat angle at a successful pull shot than unsuccessful at impact (Table 2).

Table 2. Angular Kinematics of the Joints in the Comparison of Successful and Unsuccessful Pull Shots

		Seniors batsmen		Junior batsmen				
Joint angles	**Phases**	**Successful**	**unsuccessful**	**Successful**	**unsuccessful**	**W-G**	**B-G**	**Interaction**
		Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ±SD**	***P***	***P***	***P***
Left	Stance	139.86±10.36	136.27±8.21	137.78±10.01	139.15±5.18	.37	.39	.96
knee (°)	back lift	140.35±10.02	137.76±2.94	131.99±8.61	134.25±7.02	.65	.35	.41
	Impact	149.13±8.53	149.08±5.88	144.39±9.88	139.92±4.49	.47	.27	.63
Right	Stance	145.46±7.37	144.61±7.49	147.85±9.01	142.21±11.52	.48	.96	.91
knee	back lift	128.63±5.82	128.49±5.56	126.91±3.71	130.03±7.98	.69	.89	.59
(°)	Impact	139.13±12.02*	133.35±11.62	128.10±11.75	124.82±18.36	.57	.14	.36
left hip	Stance	133.86±8.52	130.15±3.68	134.59±8.34	133.58±6.83	.95	.27	.29
(°)	back lift	129.98±5.02	120.63±10.70	116.28±8.42	121.37±11.24	.52	.09	.07
	Impact	148.29±9.38*	138.77±10.45*	135.21±11.85*	118.78±9.11*	.00	.02	.22
Right	Stance	149.72±9.59	150.15±4.65	151.14±11.47	150.66±6.86	.00	.05	.01
hip	back lift	143.17±9.48	148.36±6.18	142.86±13.89	139.73±8.66	.72	.43	.37
(°)	impact	157.24±3.28	154.87±8.48	155.95±9.40*	146.94±5.29*	.01	.33	.38
Bat	back lift	87.55±9.10	88.71±6.44	88.82±4.63	88.75±8.88	.51	.98	.34
(°)	impact	79.93±7.42*	92.34±6.32*	83.92±8.38*	90.26±9.94*	.03	.26	.34

**The level of significance adjusted at P .05. W-G (within groups), B-G (between groups), interaction (groups and pull shots)*

The velocities of the body segments showed a significant main effect among groups in the measures of left hip, F = 3.88, P< .04, ηp2.34 (Table 3). Tukey post hoc showed the movement of the left hip of senior and junior batsmen were significantly faster at impact at successful pull shot than unsuccessful shot. There were significant main effects between-groups in bat velocity, F = 4.20, P< .04, ηp2.36. Tukey post hoc results showed the bat swing of senior and junior batsmen were significantly faster at successful than unsuccessful pull shot.

Table 3. Linear Velocities of Body Segments in the Comparison of Successful and Unsuccessful Pull Shots

	Senior batsmen		Junior batsmen				
	Successful	**unsuccessful**	**Successful**	**Unsuccessful**	**W-G**	**B-G**	**interaction**
Measure	**Mean±SD**	**Mean±SD**	**Mean±SD**	**Mean±SD**	***P***	***P***	***P***
Left knee (m/s)	1.11±.48	.93±.28	1.04±.28	.92±.39	.00	.66	.15
Right knee (m/s)	.73±.30	.73±.16	.85±.54	.68±.18	.20	.93	.61
Left hip (m/s)	1.18±.15	1.09±.13*	1.33±.34	1.23±26	.07	.04	.94
Right hip (m/s)	.62±.21	.68±.20	.61±.21	.66±.23	.43	.97	.98
Bat (m/s)	10.04±1.85*	12.14±2.57*	11.57±1.16*	13.68±2.31*	.24	.04	.11

**The level of significance adjusted at P .05. W-G (within-groups), B-G (between-groups), interaction (groups and pull shots)*

Discussion

Various cricket coaches and experts have qualitatively explained the key points of the unsuccessful pull shot. However, there was no quantitative data of successful and unsuccessful pull shot. Therefore, it is a comparison in the kinematics of successful and unsuccessful pull shots of the seniors and juniors cricket batsmen. The kinematics of the pull shot was separated into three phases, the stance, back lift, and bat-ball impact.

As figure 02 shows the backswing of bat completes over the right shoulder of a right-handed batsman. Higher back swing assists a batsman to accomplish the short-pitched ball downward (Knight, 2007; Pyke & Davis, 2010). Results showed the height of bat at impact decrease than the back lift such as senior batsmen (-.37 m), and junior batsmen (-.36m). The bat height of senior batsmen was (+.05 m) higher at the execution of a successful pull shot than the unsuccessful. The center of gravity (COG) of the batsmen vertically increases at a successful pull shot than an unsuccessful pull shot (Senior = +.08 m, and junior = + .07 m). The current study confirms the coaching suggestions that the COG of batsmen would increase vertically for a successful pull shot (Andrew, 1987; Kelly et al., 2003; Knight, 2007).

The findings of the current study contradict with Woolmer et al. (2008) by showing less stride length at successful pull shot than unsuccessful (senior batsmen = -.08 m), and (junior batsmen = .06 m).

The left knee and right knee extend at back lift such as senior (left knee = + 8.78°, right knee = +10.5), junior batsmen (left knee = + 12.63°, right knee = + 2.81°). The body weight transfer onto the right leg which becomes a supportive leg for rotation during the bat's downswing. Figure 03 shows knees and hip joints extend at impact, which increases the vertical position of the shoulder and bat. The extension of hips was higher at successful pull shot than unsuccessful shot as senior batsmen (left hip = +18.31°, right hip = +14.07°), junior batsmen (left hip = 18.99°, right hip = + 13.09°). The pull shot is played with the horizontal bat swing with the upright position of the upper body by keeping a certain distance of bat-ball impact from the position head of batsmen.

The left knee and hip of senior and junior batsmen move faster toward the short of length ball at a successful pull shot than the unsuccessful shot. It is concluded the faster movement of legs assists a batsman to execute pull shot towards the square leg and mid-wicket (Bradman, 1958). A batsman focusses to execute the pull shot with accuracy that why the control bat's velocity rather than swing vigorously (Headrick et al., 2012). The bat swing depends on the height of the back lift and bat swing time (Lund & Heefner, 2005). A cricket batsman also desires to protect himself from being caught and executes pull shot downward rather the skying. Therefore, the position of head and bat plays an important role to hit the successful pull shot. Results showed the successful pull shot was executed (0.11 m) further from the head than the unsuccessful pull shot. It confirms the coaching suggestion that bat-ball impact should occur in front of the head with the straight position of arms and bat (Bradman, 1958; Knight, 2007; Woolmer et al., 2008). The bat angle also plays an important role to execute a successful pull shot. The result showed bat angle of seniors were (-12.41°), juniors (-7.9°) lesser at successful pull than the unsuccessful pull shot. Finding of the current study support the coaching recommendation of Sir Bradman (1958) as the bat angle should be lesser than ninety degrees, Woolmer et al. (2008), and higher than 45° degree.

Conclusion

This quantitative analysis showed significant differences in the kinematics of the successful and unsuccessful pull shots. The vertical height of the bat and COG of the batsman were vertically higher at the attempt of successful than unsuccessful pull shot. The angular position of the knee and hip joints were significantly were higher at a successful pull shot. The knees and hips joints play a significant role to keep shoulder, hand and bat above the trajectory of the short-pitched ball for the successful pull shot. On the other hand, the faster movements of the left knee and left hip bring the position of a batsman earlier at the short pitch ball. Finally, the faster swing of the bat plays a significant role to execute a successful pull shot. Various findings of the current study confirm the coaching suggestions, as a higher extension of knee, hips, upright position of the trunk, faster bat's swing and bat's angle assists a batsman to execute a successfully pull shot (Andrew, 1987; Bradman, 1958). Future recommendations, research should be conducted while batsmen performing in match-like conditions against the fast blowers.

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