THE EFFECT OF DELIVERY METHOD ON CRICKET BATTING UPPER-BODY KINEMATICS

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The aim of this study was to determine the effect of delivery method on upper-body kinematics in cricketers playing a front foot drive and a back foot pull shot. Fourteen male cricketers were played both shots against a bowler, bowling machine, and Sidearm™ ball thrower. The availability of pre-release visual cues appears to affect upper-body kinematics during the pull shot but not the drive other than at the back shoulder. The Sidearm™ may represent a compromise between bowler and bowling machine when training the pull shot but coaches should consider differences in upper-body proximal-distal joint dominance.

KEYWORDS: bowling machine, bowler, Sidearm, pull, drive, perception.

INTRODUCTION: In cricket batting, determination of pre-release and early ball flight aids timely shot selection and successful contact with the ball (Land & McLeod, 2000; Stretch et al., 2000). Training conditions which dismiss specifying variables (*e.g.* pre-release bowler kinematics) may result in perception-action patterns that lack transferability to competitive performance (Renshaw et al., 2007). The utility of bowling machines in training has therefore been questioned (Pinder et al., 2011; Cotterill, 2014), despite training volume and bowler workload advantages. The lack of pre-release information when facing a bowling machine has resulted in delayed front foot stride initiation (Cork et al., 2010). Paradoxically, increased pre-knowledge of ball trajectory can also lead to elite batters initiating movement earlier (Peploe et al., 2014). The majority of research has focused on movement timings, lower-body kinematics, and front foot shots. Players and coaches would further benefit from knowledge regarding differences in upper-body kinematics, differences during back foot shots, and alternative delivery methods. The aim of the present study was therefore to determine the effect of delivery method (bowler, bowling machine, or Sidearm™ ball thrower) on upper-body kinematics in cricketers playing a front foot drive and a back foot pull shot.

METHODS:

Data Collection

Fourteen male cricketers (22 ± 3 years; 1.83 ± 0.03 m; 83.3 ± 8.2 kg) participated in this study, including 4 club, 5 County, 4 England Lions, and 1 England international player. Procedures were explained to each participant and informed consent obtained in accordance with the institutional ethics committee. Testing was conducted on a standard sized indoor artificial cricket pitch. Forty-six retro-reflective markers were attached to each batsman as well as five to their bat and five patches of reflective tape to each ball, in the same locations as a previous batting kinematics investigation (Peploe et al., 2019). Marker data were recorded using an 18 camera Vicon Motion Analysis System (250 Hz; OMG Plc, Oxford, UK).

All participants completed a self-selected warm-up and a series of familiarisation trials prior to data collection. Each performed: 9 ± 2 front foot drives and 10 ± 2 back foot pull shots successfully against a bowling machine (BOLA Professional); 6 ± 2 drives and 3 ± 1 pulls successfully against a Sidearm™ ball thrower delivered by an experienced ECB Level 4 Coach; and 4 ± 1 drives and 3 ± 1 pulls successfully against an MCCU elite university academy fast bowler. Successful trials were those impacted in the intended direction. The lower quantity of successful shots against the Sidearm™ and bowler were a consequence of greater variability in release characteristics. To replicate common training conditions, and due to lower release speeds with the Sidearm^{TM}, trials with this device were delivered from a coach-selected distance 2 - 3 m closer to the batsmen.

Data Reduction
Marker data were labelled within Vicon Nexus software. Trajectories were filtered using a recursive two-way Butterworth low-pass filter with a cut-off frequency of 15 Hz, determined via residual analysis. Local coordinate systems were defined in Visual 3D software (C-Motion Inc., Germantown, MD, USA) according to Peploe et al. (2019). In accordance with previous research (Peploe et al., 2019), events were identified corresponding to ball release, start of backswing, start of downswing, and impact. Timing of each event relative to ball release was identified for each trial, as was incoming ball speed. Twenty-five upper-body kinematic parameters were calculated for each trial describing aspects of technique associated with performance in hitting sports, or considered important by elite coaches (Table 1): 5 parameters at ball release; 9 at the start of the downswing; 8 during the downswing; and 3 at impact. Parameters were averaged for each participant in each delivery method. Parameter definitions are available in the supplementary materials (Table S1).

Statistical Analysis
All statistical analyses were performed within JASP (Amsterdam, Netherlands) software Version 0.10. A Bayesian inferential statistical approach was used to provide probabilistic statements, with each analysis using a conservative default 'noninformative' prior. One-way repeated measures ANOVAs evaluated the effect of delivery method on each parameter. Bayes factor (BF_{10}) was reported to indicate the strength of the evidence for each analysis: 1/3 < *anecdotal* ≤ 3; 3 < *moderate* ≤ 10; 10 < *strong* ≤ 30; 30 < *very strong* ≤ 100; *extreme* > 100. Evidence for the alternative hypothesis (H_1) was set as $BF_{10} > 3$ and for the null hypothesis (H_0) $BF_{10} < 1/3$. Where a meaningful BF_{10} was reported, a Bayesian post-hoc was performed.

RESULTS: Incoming ball speed was greatest in the bowling machine condition, and lowest in the Sidearm^{TM} condition (Table 1; drives: $BF_{10} = 2.5 \times 10^{16}$, *extreme*; pulls: $BF_{10} = 5.7 \times 10^{16}$, *extreme*). Time from ball release to impact was shorter for the Sidearm^{TM} condition than the bowling machine or bowler (drives: $BF_{10} = 41395$, *extreme*; pulls: $BF_{10} = 4.6 \times 10^{6}$, *extreme*). Detailed results of all post-hoc tests are available in the supplementary materials (Table S2).

Drives
There was no meaningful difference in timing of backswing initiation relative to ball release between the delivery methods ($BF_{10} = 0.908$, *anecdotal*). The downswing begun later relative to ball release in the Sidearm^{TM} condition compared to the other two delivery methods (BF_{10} = 94.2, *very strong*). At ball release, the only difference in upper-body kinematic parameters was a more flexed thorax in the bowler condition compared to the other delivery methods (BF_{10} = 125, *extreme*). The only meaningful differences at the start of the downswing were less back shoulder extension ($BF_{10} = 1.0 \times 10^{6}$, *extreme*) and adduction ($BF_{10} = 23233$, *extreme*) against the bowling machine compared to the other delivery methods. There were no meaningful differences between conditions during the downswing or at impact, with numerous parameters revealing evidence for the null hypothesis ($0.180 \leq BF_{10} \leq 1.08$; Table 1).

Pulls
The backswing was initiated earlier relative to ball release in the bowler condition compared to the other delivery methods (Table 1; $BF_{10} = 1195$, *extreme*). Downswing initiation was most delayed in the Sidearm^{TM} condition ($BF_{10} = 2628$, *extreme*). At ball release, participants exhibited a more flexed thorax against the bowler compared to the other two delivery methods ($BF_{10} = 17271$, *extreme*), and their bat was pulled back further about the global medio-lateral axis in the bowling machine compared to Sidearm^{TM} condition ($BF_{10} = 11.4$, *strong*) and about

the global anterior-posterior axis in the Sidearm^{TM} compared to bowler condition (BF_{10} = 3.03, *moderate*). At the start of the downswing, frontal plane pelvis-thorax separation was greatest

Table 1: Effect of delivery method (BM: bowling machine; S: Sidearm^{TM}; B: bowler) on cricket batting upper-body kinematics.

parameter (° unless stated)	drives BM	drives S	drives B	drives BF_{10}	pulls BM	pulls S	pulls B	pulls BF_{10}
incoming ball speed ($m \cdot s^{-1}$)	34.7 ± $2.0^{\#\$}$	27.7 ± $0.7^{*\$}$	32.9 ± $0.7^{*\#}$	**2.5×10^{16}**	34.3 ± $1.7^{\#\$}$	28.0 ± $0.4^{*\$}$	32.9 ± $0.8^{*\#}$	**5.7×10^{16}**
time from BR to start of backswing	0.124 ± 0.059	0.142 ± 0.075	0.116 ± 0.051	0.908	0.161 ± $0.059^{\$}$	0.164 ± $0.085^{\$}$	0.101 ± $0.060^{*\#}$	**1195**
time from BR to SDS	0.367 ± $0.058^{\#}$	0.423 ± $0.043^{*\$}$	0.379 ± $0.041^{\#}$	**94.2**	0.381 ± $0.045^{\#}$	0.431 ± $0.057^{*\$}$	0.358 ± $0.058^{\#}$	**2628**
time from BR to IMP	0.544 ± $0.052^{\#}$	0.614 ± $0.032^{*\$}$	0.556 ± $0.037^{\#}$	**41395**	0.588 ± $0.050^{\#}$	0.659 ± $0.046^{*\$}$	0.580 ± $0.039^{\#}$	**4.6×10^{6}**
pelvis transverse plane rotation BR	-69.6 ± 5.2	-69.9 ± 5.1	-69.6 ± 6.5	*0.185*	-71.2 ± 4.8	-70.6 ± 5.1	-70.6 ± 6.4	*0.231*
thorax transverse plane rotation BR	-68.6 ± 4.4	-69.6 ± 3.8	-69.3 ± 4.0	1.317	-70.0 ± 3.7	-69.9 ± 4.0	-69.9 ± 3.9	*0.175*
thorax frontal plane rotation BR	-37.9 ± $9.2^{\$}$	-37.8 ± $9.7^{\$}$	-40.4 ± $9.6^{*\#}$	**125**	-36.2 ± $9.3^{\$}$	-37.4 ± $9.9^{\$}$	-40.1 ± $10.0^{*\#}$	**17271**
bat rotation about global medio-lateral axis BR	-112.4 ± 23.9	-113.0 ± 19.5	-108.5 ± 20.3	0.549	-107.8 ± $24.1^{\#}$	-102.3 ± 21.1*	-99.6 ± 22.7	**11.4**
bat rotation about global anterior-posterior axis BR	-13.6 ± 11.8	-15.2 ± 12.3	-16.2 ± 11.4	0.541	-20.0 ± 12.4	-21.1 ± $10.1^{\$}$	-17.1 ± $9.0^{\#}$	**3.03**
pelvis-thorax transverse plane separation SDS	10.4 ± 3.8	11.0 ± 2.5	11.6 ± 3.6	0.399	7.4 ± 3.2	7.0 ± 4.1	6.3 ± 5.0	*0.278*
pelvis-thorax frontal plane separation SDS	20.3 ± 8.0	20.5 ± 7.6	22.1 ± 8.2	2.41	9.0 ± $9.4^{\#\$}$	11.4 ± $8.8^{*\$}$	16.9 ± $8.9^{*\#}$	**679935**
front shoulder flexion / extension angle SDS	49.5 ± 9.0	50.0 ± 7.5	51.3 ± 8.7	0.539	56.0 ± 8.6	59.0 ± 10.2	54.5 ± 10.6	**3.94**
front shoulder abduction / adduction angle SDS	-9.5 ± 9.8	-14.3 ± 7.6	-12.5 ± 9.9	1.64	-15.2 ± 8.7	-15.8 ± 9.6	-12.0 ± 12.0	1.04
back shoulder flexion / extension angle SDS	-16.3 ± $12.0^{\#\$}$	-37.4 ± 13.2*	-34.3 ± 12.5*	**1.0×10^{6}**	-15.0 ± 11.4	-10.5 ± 14.1	-18.7 ± 16.9	2.20
back shoulder abduction / adduction angle SDS	-25.5 ± $9.4^{\#\$}$	-35.8 ± 9.8*	-36.8 ± 11.8*	**23233**	-23.4 ± $8.4^{\#\$}$	-38.6 ± 9.5*	-38.5 ± 11.0*	**9.3×10^{6}**
front elbow angle SDS	111.3 ± 11.8	114.4 ± 10.3	113.3 ± 11.5	0.969	112.0 ± 11.3	111.3 ± 11.3	108.8 ± 12.2	1.57
back elbow angle SDS	59.6 ± 10.6	60.8 ± 9.1	60.0 ± 7.7	*0.230*	57.5 ± 8.5	57.0 ± 8.6	58.1 ± 6.9	*0.252*
bat to forearm angle SDS	121.7 ± 6.4	122.7 ± 9.9	122.5 ± 10.8	*0.202*	121.9 ± $9.0^{\$}$	123.5 ± 10.8	126.6 ± 9.4*	**61.5**
front shoulder flexion / extension DS	36.4 ± 9.1	34.9 ± 8.9	33.3 ± 13.2	0.335	13.9 ± 9.1	11.7 ± 10.6	9.7 ± 16.7	*0.290*
front shoulder abduction / adduction DS	14.2 ± 9.0	14.9 ± 5.4	13.1 ± 7.6	*0.229*	18.6 ± 9.8	23.2 ± 9.5	23.7 ± 13.5	1.10
back shoulder flexion / extension DS	69.5 ± 14.6	72.1 ± 13.9	69.1 ± 12.2	0.524	64.5 ± 19.5	65.7 ± 19.1	64.0 ± 27.6	*0.184*
back shoulder abduction / adduction DS	14.4 ± 7.0	14.8 ± 7.0	14.6 ± 9.4	*0.180*	11.9 ± $8.5^{\#\$}$	21.1 ± 8.9*	20.1 ± 11.1*	**81.4**
front elbow extension DS	11.7 ± 10.3	15.4 ± 12.5	17.8 ± 12.2	1.08	26.6 ± 12.6	27.0 ± 11.7	17.6 ± 18.4	**3.43**
back elbow extension DS	40.4 ± 10.2	45.1 ± 13.8	45.6 ± 13.7	0.974	69.3 ± $10.3^{\#}$	74.2 ± $10.4^{*\$}$	59.4 ± $17.1^{\#}$	**182**
max distal bat linear speed DS ($m \cdot s^{-1}$)	19.5 ± 1.3	20.3 ± 1.7	19.9 ± 2.1	0.445	21.8 ± 1.1	21.8 ± 1.6	21.5 ± 2.0	*0.274*
max bat angular velocity DS ($° \cdot s^{-1}$)	1403 ± 123	1441 ± 149	1431 ± 221	*0.219*	1784 ± 172	1717 ± 220	1824 ± 389	0.390
pelvis-thorax transverse plane separation IMP	6.4 ± 5.5	6.2 ± 5.8	4.4 ± 6.2	0.492	-7.7 ± 6.1	-9.6 ± 3.8	-7.9 ± 6.8	0.396
pelvis-thorax frontal plane separation IMP	11.8 ± 9.6	10.2 ± 8.9	10.0 ± 11.4	*0.281*	-7.1 ± 6.7	-8.7 ± $7.8^{\$}$	-3.9 ± $8.6^{\#}$	**31.5**
bat to forearm angle IMP	145.5 ± 6.7	146.9 ± 10.7	142.8 ± 14.0	0.365	164.1 ± 8.2	165.7 ± 8.5	163.2 ± 13.7	*0.272*

Note: BR: ball release; SDS: start of downswing; DS: downswing; IMP: impact; green/bold: meaningful H_1; *red/italics*: meaningful H_0; *: different to BM; #: different to S; $: different to B.

against the bowler and least against the bowling machine (BF_{10} = 679935, *extreme*). The back shoulder was least adducted against the bowling machine ($BF_{10} = 9.3 \times 10^6$, *extreme*) and the bat was more cocked at the wrist against the bowling machine compared to the bowler (BF_{10} = 61.5, *very strong*). During the downswing, magnitudes of back shoulder adduction were lowest against the bowling machine (BF_{10} = 81.4, *very strong*) and the back elbow extended the most against the Sidearm™ (BF_{10} = 182, *extreme*). The follow-through pelvis-thorax separation in the frontal plane was lower at impact against the bowler compared to the Sidearm™ (BF_{10} = 31.5, *very strong*). No other meaningful differences between conditions were reported (Table 1).

DISCUSSION: Despite the ball being released from 2 - 3 m closer, the time between ball release and impact was greater against the Sidearm™ than either of the other two delivery methods. As a likely consequence of this, participants began their downswing later against the Sidearm™. Participants stood with a more flexed thorax at ball release when facing the bowler. Kinematic differences during the batting action were dependent upon the shot being played. The only difference between conditions when playing the front foot drive was a smaller backswing magnitude at the back shoulder when facing the bowling machine, possibly due to delayed detection of specifying information. As such, the Sidearm™ appears capable of replicating realistic front foot drive upper-body kinematics, as does the bowling machine at joints other than the back shoulder. During the back foot pull shot, the availability of pre-release visual cues appeared to affect pelvis-thorax frontal plane separation (bowler > Sidearm™ > bowling machine) and back shoulder adduction (least adducted against the bowling machine) at the start of the downswing. In likely preparation for the delayed detection of visual cues, the bat was pulled further back at ball release about the global medio-lateral (bowling machine > SidearmTM) and anterior-posterior (Sidearm™ > bowler) axes. Despite seeming to represent a compromise between bowler and bowling machine conditions at ball release and during the back swing, the Sidearm™ may encourage more distal elbow dominant and less proximal pelvis-thorax dominant pull shots during the downswing.

CONCLUSION: Pre-release visual cue availability in different delivery methods appears to affect upper-body kinematics during the cricket back foot pull shot but not the front foot drive other than at the back shoulder. Delivery methods can therefore likely be used interchangeably to train front foot drive upper-body technique. The Sidearm™ may represent a compromise between bowler and bowling machine conditions when training the pull shot but players and coaches should be aware of differences in upper body proximal-distal joint dominance.

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