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The effects of different delivery methods on the movement kinematics of elite cricket batsmen in repeated front foot drives

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Abstract

The aim of this paper was to examine differences in delivery characteristics and the resulting response exhibited by ten elite cricket batsmen when hitting repeated front foot drives against three different ball delivery methods; a bowling machine, a Sidearm™ ball thrower and a bowler. Synchronous three-dimensional Vicon motion capture technology and high-speed video were used to track batsman, bat and ball motion, and a range of discrete timing and kinematic variables were extracted from the resulting biomechanical model. Results showed significant differences in speed and ball release-to-impact time between the three delivery methods, thus questioning the validity of the bowling machine and Sidearm™ in the way they are currently used as true representations of batting against a real life bowler. Findings from the timing and kinematics of the subjects' movements suggest a different technical response is also exhibited when facing the different delivery methods; for example batters were found to initiate movement earlier and have a lower maximum bat speed against the bowling machine, but initiate and complete their front foot stride earlier as well as moving their COM further forward in the Sidearm™ trials.

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1. Introduction

Elite cricket batsmen are highly attuned to a number of sources of information that aid in shot selection. By identifying these visual cues, elite batsmen can perceive pre-flight information regarding the future trajectory of

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the ball, allowing them to begin their movements before ball release (Müller et al, 2006). Due to the temporal and spatial difficulty of identifying ball arrival position and time against an elite fast bowler, this anticipatory skill is seen as essential for batting success (Müller et al, 2009). Indeed a number of studies have identified a relationship between skill level and anticipation, suggesting that elite sportspeople gain more information about future ball direction from pre-flight cues than lesser skilled players (Shim et al, 2005; Müller et al, 2006; Mann et al, 2010).

The majority of this pre-flight information is gained from visual cues during the bowler's delivery. However, many of these cues are not available when facing a bowling machine or Sidearm™ ball thrower. As a result, players rely on other cues such as the angle of the bowling machine head and information from early ball flight to time and organise their movements. It is thought that these cues are far less useful than those gained from the kinematics of a bowler's delivery, and as such a different technical response is exhibited (Pinder et al, 2011).

Several studies have investigated differences in movement timing when facing a bowling machine compared to a bowler. Gibson and Adams (1989) found a single subject to initiate their backswing and downswing later, but commence and complete their front foot stride earlier when facing a machine than a bowler. This later bat movement was attributed to a lack of information regarding ball release time against the machine, although prior knowledge of ball bounce location may have instigated the earlier front foot stride. Pinder et al (2011) also found 12 developing players to initiate their backswing and downswing later against the machine, but commence and complete their front foot stride later in the bowling machine condition. This later movement could be attributed to a lack of visual cues gained from the bowling machine increasing the batsman's reaction time, or the players' limited experience facing a bowling machine (<30 trials per week) not allowing them to adapt to its delivery characteristics. Finally Renshaw et al (2007) found four experienced players to initiate their bat swing earlier when facing the bowling machine, but found no differences in the timing of the front foot movement.

Both Renshaw et al (2007) and Pinder et al (2011) also found batsmen to exhibit a shorter front foot stride, lower backswing and slower bat speed when facing the bowling machine compared to the bowler. This was attributed to additional visual cues regarding the future ball bounce position being gained when facing the bowler, thus allowing players to organise movements earlier and display greater bat speed and stride length.

While a number of technical and timing differences have been identified between facing a bowling machine and a bowler, these studies have all been carried out using video cameras alongside the batsman sampling at 100Hz or below, and often using only a single subject or small sample (e.g. n=4) of players. There is also still some disagreement regarding the exact technical differences exhibited by batsmen when facing different delivery methods. Using a three-dimensional motion capture system sampling at a higher frame rate, this preliminary study aims to determine differences in delivery characteristics and the resulting response amongst a group of elite batsmen when facing a bowling machine and a Sidearm™ ball thrower compared to when facing a bowler.

2. Methods

2.1. Subjects

Ten male elite cricket batsmen from the England performance squads participated in this study. They ranged in age from 17 to 25 years ($M = 20.8 \pm 2.2$), had an average height of 1.80 ± 0.04 m and an average body mass of 80.1 ± 7.8 kg. Subjects included one batsman with full international playing honours, three from the England Lions squad and six that had represented England under 19's. All ten subjects gave informed consent in accordance with the Loughborough University ethical advisory committee procedures.

2.2. Experimental Setup

Data collection took place at the National Cricket Performance Centre at Loughborough University. 18 Vicon MX cameras were positioned on tripods around a netted batting lane in order to capture the position of the batsman, bat and incoming ball with time. Two synchronous high-speed video cameras also captured a view of the pitch such that the timing of ball release and bounce could be determined. Both the Vicon system and high-speed

video cameras captured at 250 Hz. The centre of the batting area was defined by a Kistler force plate sampling at 1000 Hz, from which the subjects were instructed to begin each stroke.

2.3. Data Collection Protocol

On arrival subjects put on their batting kit, and a full body set of 46 spherical retro-reflective markers was applied (Fig. 1). An additional five markers were placed on the bat, and six on the stumps. Finally, five squares of retro-reflective tape were applied to the ball such that its position could be tracked using the Vicon system.



Fig. 1. Full body marker set used for motion capture trials

After a number of warm up strokes determined by the batsman, subjects were asked to perform twelve front foot drives against a bowling machine. The front foot drive was selected for investigation because it is a fundamental attacking stroke required by all players. Batsmen were encouraged to execute their shots as they would in a match, aiming to hit the ball for four runs on the ground directly past the bowler. The projected balls bounced approximately in line with off stump 3 m in front of the batting crease, although the mechanical discrepancy of the machine produced some of trial-to-trial variation in speed and bounce position.

Next subjects faced a series of balls delivered by a national standard ECB level 4 coach, with significant experience coaching the participants involved, using a Sidearm™ ball thrower. Initially subjects received ten full-pitched deliveries for the front foot drive in block fashion. A further twenty trials were then completed, but this time with a randomised delivery length such that the player had no prior knowledge of what shot to play. In order to maintain the realism of this study with a normal coaching session, the Sidearm™ trials were delivered from 2-3 yards closer to the batsman. This change in distance was judged by the coach, and is designed to accommodate for the lower speeds attainable when using the Sidearm™. Clearly due to the expert skill required to repeatedly hit the same area of the pitch, the ball bounce location was far less consistent with the Sidearm™ than the bowling machine. As such an average of only 8.1 ± 1.2 Sidearm™ trials produced a successful front foot drive.

Finally, subjects faced twenty deliveries from a fast bowler of a similar playing level to themselves. Four right arm bowlers were used; each had limited experience of playing against the participants of this study, and was required to bowl at either two or three batsmen in turn. The coach instructed the bowlers in secret where to target each delivery, with the aim of randomizing ball bounce length but ensuring a suitable number were aimed at a full length to prompt the batsman into a front foot drive. This was intended to replicate as closely as possible the match performance of each batsman. Again due to the low repeatability of the bowler, and required shot decision making of the batsman, on average only 3.6 ± 0.7 successful front foot drives were completed for each subject.

2.4. Timing of events

Motion capture data was reconstructed and labeled in Vicon Nexus software, then a biomechanical model was applied to each hitting trial using Visual 3D biomechanics software. Seven events were identified from the motion capture data using automated Visual 3D code, and expressed relative to the time of bat-ball impact ($t = 0$ ms): (i)

ball release (ii) start of backswing (iii) initiation of front foot stride (iv) start of bat downswing (v) completion of front foot stride (vi) ball bounce and (vii) bat-ball impact (Fig. 2). Timings for ball release and bounce were extracted from the synchronous high-speed video, and ball speed was measured using a Trackman™ radar unit.

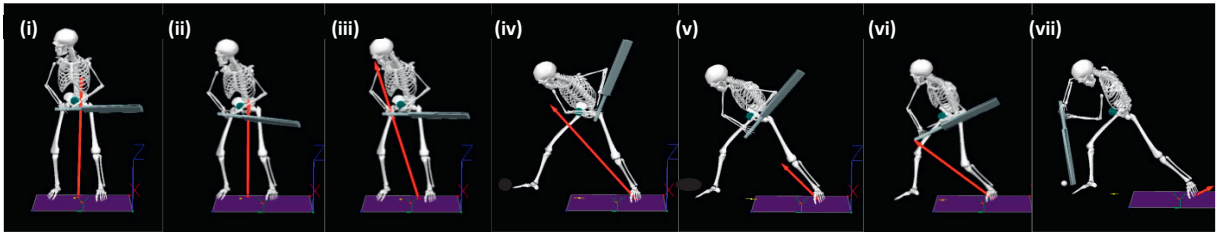


Fig. 2. The seven key events identified from each dynamic trial in the biomechanical model (i) ball release; (ii) start of backswing; (iii) initiation of front foot stride; (iv) start of bat downswing; (v) completion of front foot stride; (vi) ball bounce and (vii) bat-ball impact

2.5. Movement durations

Once events had been identified, the duration of various components of the batting stroke were assessed. Backswing, downswing and front foot stride duration were calculated from the event timings of each trial. A measure of movement initiation time (MIT) was defined as the time between ball release and the first recorded movement. Positive values denote trials where movement began after ball release, and negative values were used when it occurred before. Finally the total movement time, from first movement to impact, was also determined.

2.6. Kinematic measures

Several kinematic variables were also output from the motion capture data, based on previous literature (Renshaw et al, 2007; Pinder et al, 2011) and coaching manuals (ECB, 2009). Initially measures of front foot stride length and the angle of flexion in the front knee at the time of impact were recorded. The magnitude of forward movement seen in the batsman's centre of mass between movement initiation and impact was also calculated. Finally bat angle relative to the lab floor (such that 0° represented the bat upright with the handle pointing upwards, and -90° represented the bat parallel to the pitch with the blade pointing back towards the stumps) and peak bat endpoint velocity in the downswing were also assessed.

2.7. Analysis of data

Only trials where a successful impact between the bat and ball, according to the scale proposed by Weissensteiner et al (2009), were selected for analysis (bowling machine [BM] $n = 10.1 \pm 1.1$, Sidearm™ known [SA_K] $n = 4.1 \pm 0.9$, Sidearm™ unknown [SA_U] $n = 4.0 \pm 1.2$, [B] bowler $n = 3.6 \pm 0.7$). Separate one-way within-subjects ANOVAs were used to analyse each dependent variable. In cases where the sphericity assumption was violated, a Greenhouse-Geisser correction was used to adjust the degrees of freedom of the repeated variables in the ANOVAs. Post-hoc pairwise comparisons, with Bonferroni corrections to reduce the risk of type 1 errors in multiple comparisons, were then carried out to assess significant differences between individual delivery methods.

3. Results

3.1. Delivery method

One-way within-subjects analyses revealed some significant differences between delivery methods. Ball speed was found to be significantly different between delivery methods [$F(3,27) = 757.3$, $p < 0.001$] (BM $M = 82.0 \pm 1.2$ mph; SA_K $M = 63.4 \pm 0.7$ mph; SA_U $M = 63.9 \pm 1.1$ mph; B $M = 77.1 \pm 1.0$ mph). The time between ball release and impact was also significantly different between delivery methods [$F(3,27) = 212.2$, $p < 0.001$] (BM $M =$

0.497±0.011s; SA_K $M = 0.600 \pm 0.007$ s; SA_U $M = 0.601 \pm 0.014$ s; B $M = 0.536 \pm 0.015$ s). Finally analysis of the timing of bounce measured as a percentage of total ball release-to-impact time, and thus assumed to identify any changes in bounce length, revealed no significant differences between delivery methods (BM $M = 83.6 \pm 1.6\%$; SA_K $M = 85.2 \pm 2.7\%$; SA_U $M = 85.2 \pm 3.0\%$; B $M = 83.7 \pm 5.4\%$).

3.2. Movement timings

Analysis of batting events revealed that subjects began their front foot stride earlier relative to the time of impact in the Sidearm™ condition than when facing the bowler [$F(1.79, 16.1) = 7.235$, $p < 0.05$]. Trends also suggest ($p = 0.08$) that players began their stride earlier against the Sidearm™ than the bowling machine (BM $M = 0.399 \pm 0.062$ s; SA_K $M = 0.450 \pm 0.053$ s; SA_U $M = 0.450 \pm 0.049$ s; B $M = 0.383 \pm 0.073$ s). Batsmen were found to complete their stride earlier relative to impact time in the Sidearm™ condition than when facing the bowling machine [$F(3,27) = 2.482$, $p < 0.05$] (BM $M = 0.065 \pm 0.034$ s; SA_K $M = 0.086 \pm 0.045$ s; SA_U $M = 0.094 \pm 0.0037$ s; B $M = 0.070 \pm 0.030$ s). No statistically significant differences were found regarding timing of the bat swing.

3.3. Movement durations

Analysis of MIT (Fig. 3a) revealed that players began their movements significantly earlier [$F(2.1, 18.5) = 12.3$, $p < 0.001$] when facing the bowling machine than when facing the Sidearm™ (BM $M = 0.050 \pm 0.078$ s; SA_K $M = 0.133 \pm 0.065$ s; SA_U $M = 0.136 \pm 0.060$ s; B $M = 0.102 \pm 0.052$ s). Trends also suggest that the total movement time in the Sidearm™ trials was longer than when facing the bowler ($p = 0.08$).

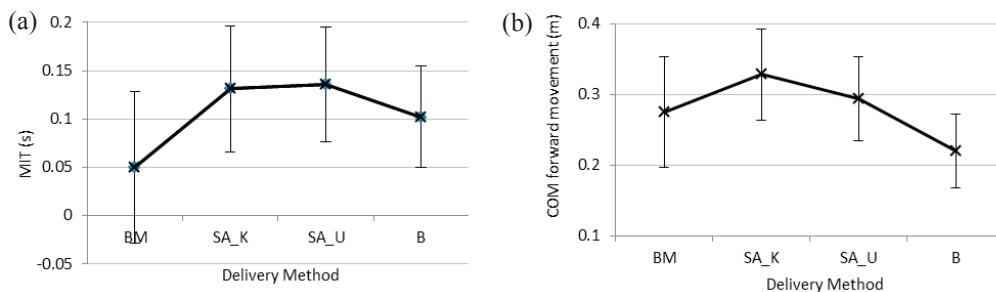


Fig. 3. Graphs of (a) movement initiation time and (b) centre of mass forward movement for each delivery method (BM = bowling machine, SA_K = Sidearm™ known, SA_U = Sidearm™ unknown, B = bowler)

3.4. Kinematic measures

Analysis of kinematic measures found subjects to exhibit a significantly higher bat angle at the start of their backswing [$F(1.8, 116.6) = 14.4$, $p < 0.001$] in the bowling machine trials than the bowler and Sidearm™ (BM $M = -112.4 \pm 29^\circ$; SA_K $M = -106.6 \pm 26.3^\circ$; SA_U $M = -106.4 \pm 25.9^\circ$; B $M = -103.0 \pm 24.8^\circ$). Batsmen were also found to move their centre of mass further forward between movement initiation and impact (Fig. 3b) [$F(3, 27) = 13.0$, $p < 0.001$] when facing the Sidearm™ than the bowler (BM $M = 0.276 \pm 0.08$ m; SA_K $M = 0.328 \pm 0.092$ m; SA_U $M = 0.294 \pm 0.069$ m; B $M = 0.220 \pm 0.075$ m). Finally batsmen displayed significantly lower bat speeds [$F(3,27) = 6.6$, $p < 0.01$] in the bowling machine condition than when facing the Sidearm™ and bowler (BM $M = 18.9 \pm 1.3$ m/s; SA_K $M = 20.2 \pm 1.4$ m/s; SA_U $M = 20.8 \pm 1.32$ m/s; B $M = 20.4 \pm 1.8$ m/s).

4. Discussion and conclusions

The purpose of this paper was to investigate the differences in delivery characteristics and the resulting technical response exhibited by elite batsmen when hitting repeated front foot drives against three different cricket ball delivery methods; a bowling machine, a Sidearm™ and a bowler.

Results showed ball speed between delivery methods to be significantly different, with speeds from the bowling machine being faster than those from the bowler, which were in turn faster than those from the Sidearm™. By delivering the ball from closer with the Sidearm™ the coach aimed to replicate the temporal challenge of facing a bowler, however the time between ball release and impact was still significantly longer. This difference in total release-to-impact time calls into question the validity of the Sidearm™ in the way it is currently used by coaches, as a true representation of batting against a real life fast bowler.

Findings regarding the timing of movement and kinematics of each subject suggest that a different technical response is adopted by batsmen when facing the three delivery methods. It is unsurprising that, given the Sidearm™ trials took significantly longer to reach the batsman, in absolute terms the front foot stride began and ended earlier relative to the time of impact. The fact that players moved further forward and over a longer time period when facing the Sidearm™ suggests a fine attunement to incoming ball speed, or a variable known as ‘time-to-contact’, indicating that players are aware they have more time to execute the stroke and as such take longer and move further to ensure a higher likelihood of a successful impact.

The fact that subjects initiated movement earlier against the bowling machine could be attributed to their increased knowledge of future ball bounce position, suggesting they are able to begin organizing their movements based on this knowledge rather than having to wait for information from the bowler’s action or early ball flight. However it is also possible that, due to the increased ball speed and shorter time given to execute the stroke, movement is forced to begin earlier against the machine in order to ensure successful contact. The same explanation can be used for the higher bat angle seen at the start of backswing, suggesting that players hold their bat higher in preparation due to the shorter time given to execute the shot.

Finally the lower bat swing speed exhibited in the bowling machine trials gives weight to the theory that batsmen have a detailed knowledge of ball bounce location before release, suggesting that they bat in a more ‘lazy’ fashion against the machine, not needing the full capability of their technique to successfully impact the ball.

The results obtained from this paper highlight a range of differences in delivery characteristics and batsman response when facing the three ball delivery methods investigated. This calls into question the validity of both the bowling machine and Sidearm™ in their current form as training aids that effectively mimic the delivery of a bowler. Further work is required in gaining additional player data to confirm or deny the theories presented above.

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