Journal of Sports Sciences

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rjsp20

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To cite this article: Mikael Jamil, Samuel Kerruish, Marco Beato & Stuart A. McErlain-Naylor (2022): The effects of bowling lines and lengths on the spatial distribution of successful power-hitting strokes in international men's one-day and T20 cricket, Journal of Sports Sciences, DOI: 10.1080/02640414.2022.2148074

To link to this article: https://doi.org/10.1080/02640414.2022.2148074

Published online: 21 Nov 2022.

JOURNAL OF SPORTS SCIENCES
https://doi.org/10.1080/02640414.2022.2148074

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The effects of bowling lines and lengths on the spatial distribution of successful power-hitting strokes in international men's one-day and T20 cricket

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ABSTRACT

This study examined 503 power-hitting strokes that resulted in the maximum of 6-runs being scored in international men's one-day and T20 cricket. Chi-Squared analyses were conducted to determine if performance and situational variables were associated with the distribution (direction) of aerial power-hitting strokes. Results revealed that bowling length, bowling line, bowler type and powerplays were all significantly ($p < 0.001$) associated with ball-hitting distribution. Post-hoc analysis of the standardised residuals revealed that greater than expected 6's were scored behind square and were associated with short-pitched bowling, fast bowling and the power-play. Similarly, bowling the half-volley length and the outside off line resulted in greater than expected 6's on the off-side. The results suggest that bowlers should try to avoid offering width outside the off stump as well as bowling the half-volley and short-pitched lengths as these bowling lines and lengths present batters with greater opportunities to score maximum runs. Fast bowling is revealed to be more susceptible to power-hitting strokes than spin bowling. Conversely, batters may wish to target the areas behind square or on the off-side for opportunities to score maximum runs, and they should look to take full advantage of the powerplay field restrictions.

ARTICLE HISTORY
Received 20 May 2022
Accepted 10 November 2022

KEYWORDS
Batting; boundary; performance analysis; ball direction; powerplay; aerial shots

Introduction

Cricket is an international team sport that is played between two teams that comprise of batters and bowlers, all of whom will be required to contribute to fielding (Scanlan et al., 2016). The objectives of batters include scoring runs and protecting their wickets (not getting out), whereas the objectives of their opposing bowlers are to restrict the number of runs they concede, whilst also attempting to take the wickets of their opposing batters (Douglas & Tam, 2010). This dynamic interaction between bowler and batter is further complicated by rules which influence field restrictions, commonly known as powerplays, where only a select number of fielders are permitted outside of the 30-yard markings on the playing field (ICC, 2021a, 2021b). Throughout the contest between batter and bowler, batters will exhibit a repertoire of attacking and defensive strokes, whilst facing a range of bowling styles commonly consisting of either fast or spin bowling variations (Mehta et al., 2022; Sarpeshkar & Mann, 2011; R. A. Stretch et al., 2000). Previous studies have revealed many key performance indicators for batters in cricket including their ability to clear the boundary, which is considered a major contributor to success in *limited overs cricket* (Douglas & Tam, 2010; Irvine & Kennedy, 2017; Petersen, 2017; C. Petersen et al., 2008).

Limited overs international cricket exists in two forms, the 50-over One Day International (ODI) format and the 20-over, International Twenty20 (IT20) form (ICC, 2021a, 2021b). Research has suggested that the shorter T20 format has made the game more physically challenging for both batters and bowlers, primarily as this format necessitates a higher rate of run-scoring and stroke play (Scanlan et al., 2016). In turn, this has increased the pressure upon bowlers to maintain accuracy and thereby diminished their margins for error (Douglas & Tam, 2010). Similarly, greater demands have been placed upon batters as this format necessitates more frequent high-intensity actions, such as running and sprinting (C. J. Petersen et al., 2010). As argued by Scanlan et al. (2016), these differing game formats could impose unique requirements upon players.

Whilst previous research has investigated the technique factors associated with greater power hitting distance by batters (McErlain-Naylor, Peploe et al., 2021; Peploe et al., 2018, 2019) and greater ball speed (Felton & King, 2016; Felton et al., 2020; Ramachandran et al., 2021) and spin (L. Sanders et al., 2018, 2019) by bowlers, it should be acknowledged that "optimal" batting or bowling performance is a result of many contributing factors including technical, tactical, and contextual aspects (McErlain-Naylor, King et al., 2021; McErlain-Naylor, Peploe et al., 2021). Furthermore, the inter-dependency of the batter–bowler interaction (Chris Peploe et al., 2014; Mcerlain-naylor et al., 2020; Sarpeshkar et al., 2017) has been relatively overlooked in previous studies, where batting or bowling have been analysed in isolation. As stated by Petersen (2017), ball-hitting distribution relative to the pitch is partly dependent on the intention and accuracy of the bowler with regards to the line and length of their delivery. Evidence of the inter-dependent bowler–batter interaction has been noted in

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previous research. For example, ball trajectory has been revealed to impact batters pre-impact movement (Sarpeshkar et al., 2017). In addition, bowlers' delivery methods have been revealed to influence batters' response times, particularly when playing front-foot strokes (Chris Peploe et al., 2014). Similarly, Mcerlain-naylor et al. (2020), discovered that delivery method and associated pre-release visual cues affected upper body kinematics of batters when playing both front and back-foot batting strokes. Postural cues in the bowler's delivery stride as they approach the crease have also been revealed to influence a batter's anticipation of events (Williams & Jackson, 2019).

Taking the above into consideration, the purpose of this study is to examine how bowling line and length can impact the direction of successful power-hitting batting strokes in international level *limited overs cricket*. This study will focus exclusively on aerial batting strokes that resulted in 6-runs being scored, the maximum available to any batter whilst facing a bowling delivery. Furthermore, this study will determine whether other factors such as competition format (ODI or IT20), field restrictions (powerplays), bowling hand (left or right) or bowling variations (fast, medium or spin) are associated with power-hitting distributions.

Methods

Data and design

Data on successfully executed power-hitting strokes were compiled across two international men's tournaments, the ICC Men's One-Day International World Cup 2019 and the ICC Men's International T20 World Cup 2016. Secondary data were obtained from Opta (London, UK) and high levels of reliability have been previously reported (Jamil et al., 2021). The original sample consisted of 590 aerial power-hitting strokes that resulted in a maximum of 6-runs being scored. Eighty-seven of these strokes were removed from the sample due to them being coded as "top-edge" – unintentional strokes often executed successfully by chance (Khan et al., 2017). These "edges" are not traditional, controlled cricket shots and often present wicket taking opportunities to the fielding team (Khan et al., 2017; Regan, 2012). Consequently, these strokes were excluded from the final sample in order to maintain the focus of this study on intentional power hitting and subsequent recommendations. This resulted in a final sample size of (n = 503) controlled (assumed deliberate) aerial power-hitting strokes, each of which resulted in 6-runs being scored. The data set consisted of variables including: bowling line; bowling length; bowling hand; bowling type; competition format; and power-play (see, Table 1 for definitions). The effects of each of these variables upon post-impact ball-distribution were examined.

In the primary analyses, all 503 strokes were categorised as landing (post-batter connection) either behind square or in-front of square (Figure 1). In the secondary analyses, the cricket pitch was divided into three segments and all strokes were categorised as either ZONE 1, ZONE 2 or ZONE 3. The angles of ball distribution were mirrored for right-handed and left-handed batters (Figure 2). Figures 3 and 4 present an illustration of the bowling length and line categorisations analysed in this study, respectively. Ethical approval for this study was obtained by the ethics committee of the local institution.

Statistical analysis

Chi-Squared (χ^2) tests of independence were conducted to determine whether there was any association between

Table 1. Definitions list for all variables provided by the data supplier.

Variable		Definition
Bowling Length*	Back of a Length	A delivery short of a good length, but fuller than a short ball, which the batsman would ordinarily look to play off the back foot.
	Full Toss	A delivery that reaches the batsman in his normal stance without pitching.
	Half Volley	An over-pitched delivery between a good length and a Yorker.
	Length Ball	A delivery of a good length. This is a length that can put the batsman in two minds whether to play the ball off the front or back foot.
	Short Ball	A delivery which is well short of a length. For a quicker bowler this is likely to be a bouncer and for a slow bowler it will ordinarily be a ball which has been dragged down.
Bowling Line*	Down Leg	When the ball pitches outside leg stump (but makes contact with the batter/bat and hence cannot be coded as a wide down leg side).
	Leg Stump	When the ball pitches partially or wholly on the leg stump
	Middle Stump	When the ball pitches partially or wholly on the middle stump
	Off Stump	When the ball pitches partially or wholly on the off stump
	Outside Off	When the ball pitches outside off stump (but makes contact with the batter/bat and hence cannot be coded as a wide outside the off side).
Bowler Hand	Right	Right handed bowlers
	Left	Left handed bowlers
Bowler Type	Fast Seam+	Typically, a bowler who regularly delivers their stock ball at high delivery speeds
	Leg Spin	Bowling, which typically deviates from the leg side to the off side after pitching
	Medium Seam+	Typically, seam bowlers who do not achieve high delivery speeds when delivering their stock ball
	Off-Spin	Bowling, which typically deviates from the off side to the leg side after pitching
Power Play	Yes	Power play fielding restrictions are being enforced
	No	Power play fielding restrictions are not being enforced
Competition	50 Over	50 over format cricket
	20 Over	20 over format cricket

*: Bowling Length and Bowling Line data were approximations and not based on XY tracking data – a highly specialised purpose designed grid system is utilised to collect this data.

+: Speed data is not based on ball tracking data

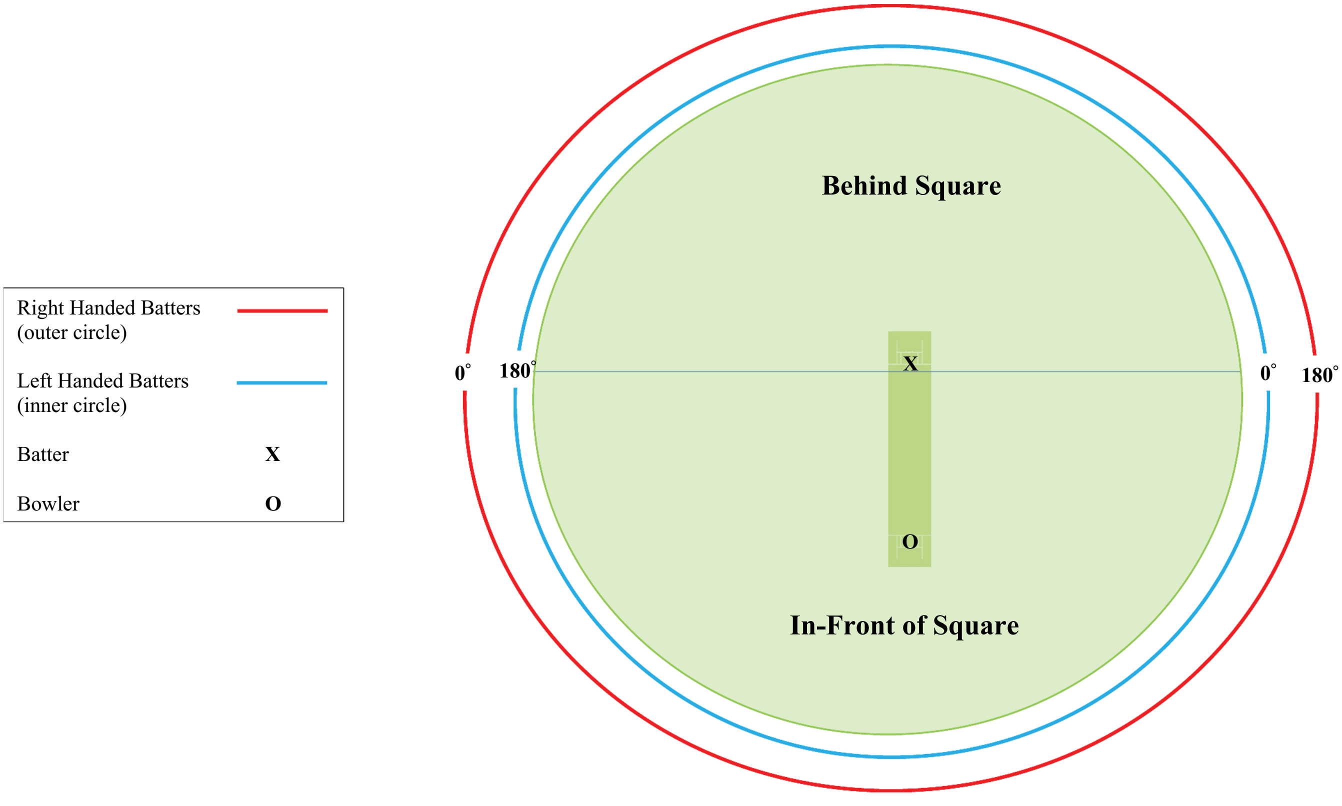

Figure 1. Ball distribution angles for both right (red) and left (blue) handed batters, behind and in-front of square.

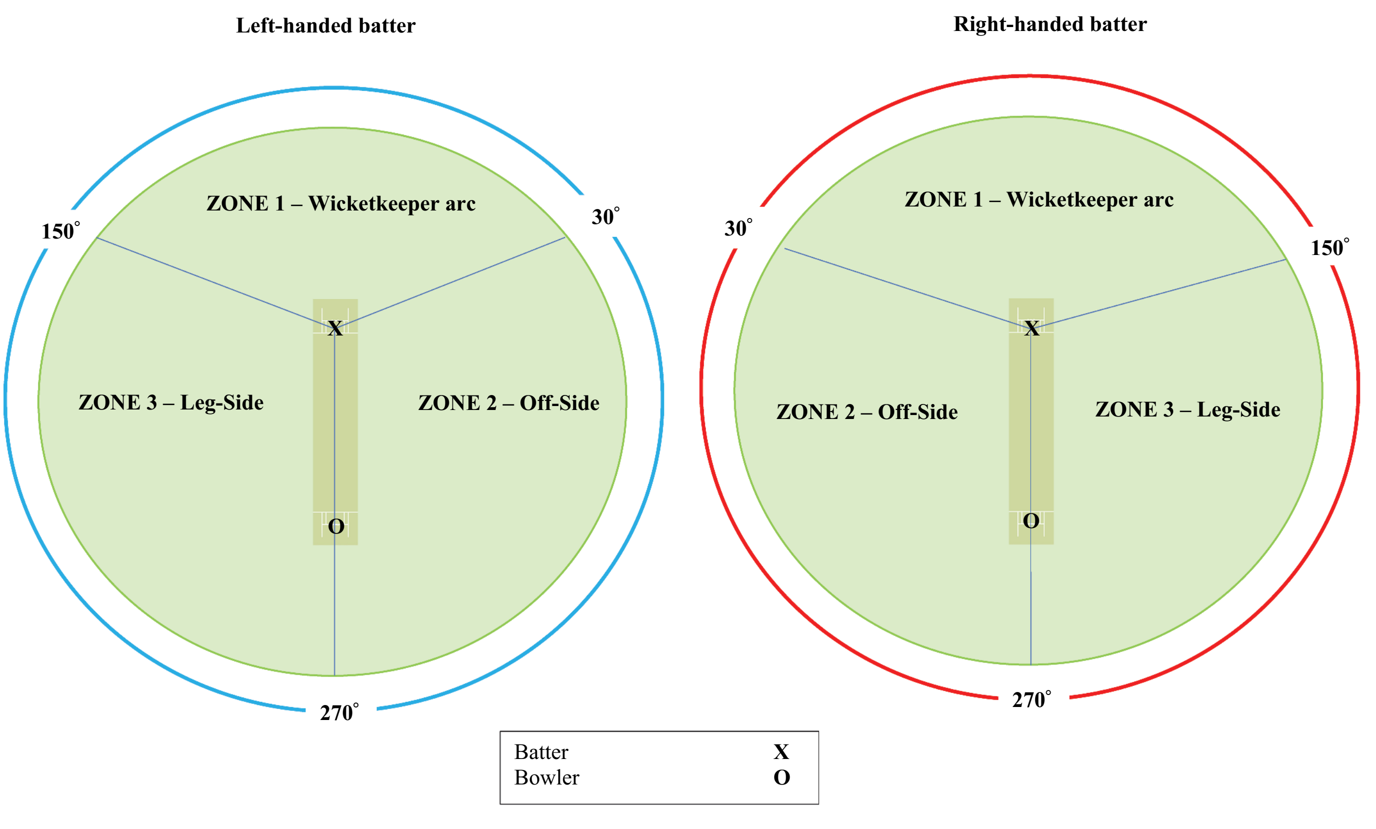

Figure 2. Ball distribution angles for left (blue) and right (red) handed batters, in all 3 (120°) zones .

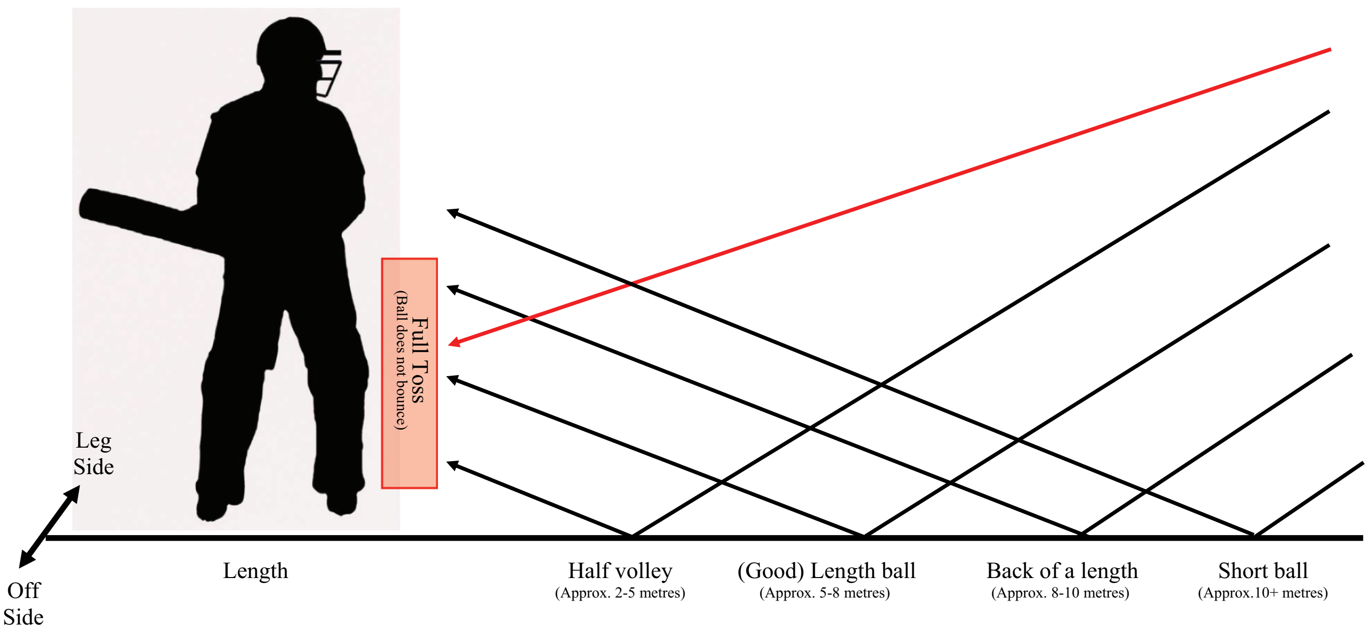

Figure 3. An illustration of bowling lengths analysed in this study. Bowling length data were not based on xy co-ordinates, but were approximations. Measurements are approximate distances from the stumps. Furthermore, heights at which the ball arrives at the batter are also approximations. (Image presents a right-handed batter).

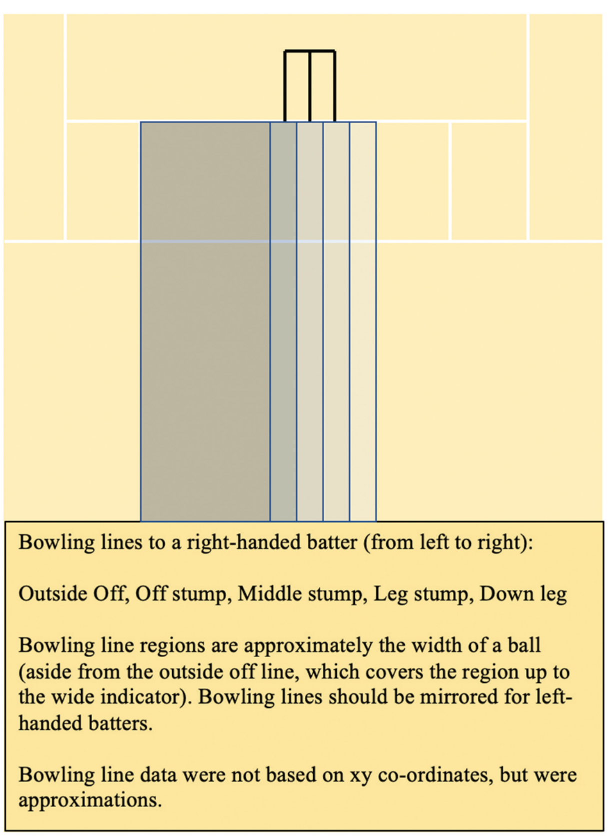

Figure 4. An illustration of bowling lines analysed in this study.

power-hitting direction frequency and each of the independent variables detailed above. Each ball bowled that resulted in the maximum of 6-runs being scored (n = 503), contributed to one and only one cell in each of the χ^2 tests conducted in this study. The values of the cell *expected* counts were greater than 5 for at least 80% of all *expected* count cells, and no

Table 2. Critical values used for Bonferroni adjusted p-values.

Variable	Primary Analysis	Secondary Analysis
Bowling Length	± 2.81	± 2.94
Bowling Line	-	± 2.94
Bowling Type	± 2.73	± 2.86
Powerplay	± 2.50	± 2.64

expected count value was less than 1 (McHugh, 2013). In cases where 2 × 2 contingency tables were formed, the Fisher's Exact test were conducted (McHugh, 2013). In the event of statistically significant ($p < 0.05$) χ^2 test results, standardised residuals were calculated to identify the specific cells making the greatest contribution to the chi-square test result and thus determine the source of the significant result (Sharpe, 2015). Bonferroni corrections were applied to account for the relatively large number of cells present in the contingency tables (Sharpe, 2015) and the associated critical values are presented in Table 2. Cramer's *V* effect sizes were also calculated (McHugh, 2013) and interpreted with the thresholds of 0.1 ≤ *small* < 0.3, 0.3 ≤ *moderate* < 0.5, and *strong* ≥ 0.5 (Cohen, 1988). All statistical analyses were performed using IBM SPSS (SPSS Statistics for Macintosh, Version 25.0. Armonk, NY: IBM Corp).

Results

Primary analysis – behind or in-front of square

Bowling length was significantly associated with ball distribution for successful aerial power hitting strokes ($p< 0.001$), with a *moderate* effect size ($V = 0.382$; Table 3). The type of bowler was significantly associated with ball distribution ($p < 0.001$), with a *small* effect size ($V = 0.248$). Finally, the powerplay overs were also revealed to be significantly associated with ball

Table 3. Chi – square test results and effects sizes.

Variable	χ^2	*p*-value (Primary Analysis)	Cramer's V	χ^2	*p*-value (Secondary Analysis)	Cramer's V
Bowling Length	73.445	< 0.001*	0.382	57.418	< 0.001*	0.338
Bowling Line	6.749	0.150	0.116	32.291	< 0.001*	0.253
Bowler Hand	0.591	0.442	0.034	1.548	0.461	0.055
Bowler Type	30.905	< 0.001*	0.248	16.746	0.010*	0.129
Power Play	28.778	< 0.001*+	0.239	14.350	< 0.001*	0.169
Competition	2.469	0.120	0.070	3.500	0.174	0.083

*: Significant at $p < 0.05$, + Results of a Fisher Exact Test reported due to 2 × 2 contingency table.

Table 4. Observed counts (Expected counts) and standardised residual values – direction of the 6 (Primary analysis).

		Behind Square	Standardised Residual	In-Front of Square	Standardised Residual	Total
Bowling Length	Back of a Length	28 (15.9)	3*	63 (75.1)	−1.4	91
	Full Toss	3 (5.9)	−1.2	31 (28.1)	0.6	34
	Half Volley	2 (17)	−3.6*	95 (80)	1.7	97
	Length Ball	26 (38.7)	−2.0	195 (182.3)	0.9	221
	Short Ball	29 (10.5)	5.7*	31 (49.5)	−2.6	60
	Total	**88**		**415**		**503**
Bowler Type	Fast Seam	69 (46)	3.4*	194 (217)	−1.6	263
	Leg Spin	6 (16.6)	−2.6	89 (78.4)	1.2	95
	Medium Seam	7 (8.6)	−0.5	42 (40.4)	0.2	49
	Off Spin	6 (16.8)	−2.6	90 (79.2)	1.2	96
	Total	**88**		**415**		**503**
Power Play	No	56 (73.1)	−2.0	362 (344.9)	0.9	418
	Yes	32 (14.9)	4.4*	53 (70.1)	−2.0	85
	Total	**88**		**415**		**503**

*: Significant at Bonferroni corrected p-values (see critical values in Table 2).

distribution ($p < 0.001$; $V = 0.239$, *small*). No significant associations were discovered between shot distribution and bowling line, bowling hand or competition format.

Post-hoc analysis of the standardised residuals (Table 4; associated critical values are reported in Table 2) revealed that short-pitched bowling, such as the short-ball (standardised residual value 5.7) and the back of a length ball (3.0), resulted in significantly greater than expected (*i.e.*, expected by chance) successful aerial power-hitting strokes behind square. The half-volley, the fullest pitched ball to reveal significant effects, resulted in significantly fewer than expected 6-run scoring strokes behind square (−3.6). Fast bowlers were revealed to concede significantly more than expected power-hitting strokes behind square (3.4). Finally, significantly more than expected power-hitting strokes were played behind square during the powerplay overs (4.4). No other significant effects were reported.

Secondary analysis – 120° zones

Bowling length was significantly associated with ball-hitting distribution ($p < 0.001$; $V = 0.338$, *moderate*; Table 3). Bowling

Table 5. Observed counts (Expected counts) and standardised residual values – direction of the 6 (Secondary analysis).

		Zone 1 (31–150)	Standardised Residual	Zone 2 (151–270)	Standardised Residual	Zone 3 (271–30)	Standardised Residual	Total
Bowling Length	Back of a Length	7 (5.1)	0.9	9 (20.3)	−2.5	75 (65.7)	1.2	91
	Full Toss	2 (1.9)	0.1	4 (7.6)	−1.3	28 (24.5)	0.7	34
	Half Volley	0 (5.4)	−2.3	40 (21.6)	3.9*	57 (70)	−1.6	97
	Length Ball	8 (12.3)	−1.2	53 (49.2)	0.5	160 (159.5)	0.0	221
	Short Ball	11 (3.3)	4.2*	6 (13.4)	−2.0	43 (43.3)	0.0	60
	Total	**28**		**362**		**113**		**503**
Bowling Line	Down Leg	4 (3.4)	0.3	3 (13.6)	−2.9*	54 (44)	1.5	61
	Leg Stump	4 (2.1)	1.4	2 (8.2)	−2.2	31 (26.7)	0.8	37
	Middle Stump	2 (3.3)	−0.7	12 (13.1)	−0.3	45 (42.6)	0.4	59
	Off Stump	6 (4.2)	0.9	12 (16.9)	−1.2	58 (54.8)	0.4	76
	Outside Off	12 (15)	−0.8	83 (60.1)	3.0*	175 (194.9)	−1.4	270
	Total	**28**		**362**		**113**		**503**
Bowler Type	Fast Seam	24 (14.6)	2.4	57 (58.6)	−0.2	182 (189.8)	−0.6	263
	Leg Spin	0 (5.3)	−2.3	19 (21.2)	−0.5	76 (68.6)	0.9	95
	Medium Seam	3 (2.7)	0.2	12 (10.9)	0.3	34 (35.4)	−0.2	49
	Off Spin	1 (5.3)	−1.9	24 (21.4)	0.6	71 (69.3)	0.2	96
	Total	**28**		**362**		**113**		**503**
Power Play	No	16 (23.3)	−1.5	96 (93.1)	0.3	306 (301.7)	0.2	418
	Yes	12 (4.7)	3.3*	16 (18.9)	−0.7	57 (61.3)	−0.6	85
	Total	**28**		**362**		**113**		**503**

*: Significant at Bonferroni corrected p-values (see critical values in Table 2).

line was also significantly associated with the direction of 6-run scoring strokes ($p < 0.001$; $V = 0.253$, *small*). Bowler type was revealed to be significantly associated with the direction of aerial power-hitting strokes ($p = 0.010$; $V = 0.129$, *small*). Finally, power-play was significantly associated with the direction of the 6-run scoring strokes ($p < 0.001$; $V = 0.169$, *small*). No significant associations were discovered between shot distribution and bowling hand or competition format.

Post-hoc analysis of the standardised residuals (Table 5; associated critical values are reported in Table 2) revealed that the short-ball resulted in greater than expected 6-run scoring strokes in ZONE 1 (4.2), representing the 120° arc behind the wicketkeeper. The half-volley resulted in greater than expected 6-run scoring strokes in ZONE 2 (3.9), which represent the off-side for both right-handed and left-handed batters. Bowling down the leg-side also resulted in fewer than expected 6-run scoring strokes in ZONE 2 (−2.9). Bowling outside off stump on the other hand resulted in greater than expected 6-run scoring strokes in ZONE 2 (3.0). Finally, significantly greater than expected power-hitting strokes were played in ZONE 1 during the powerplay overs (3.3). No other significant effects were reported.

Discussion

This study aimed to investigate factors affecting the directional distribution of aerial 6-run scoring power-hitting strokes in international men's cricket. Results revealed that bowling length, bowling line, bowler type and powerplays all significantly affected the post-impact direction of the ball, although bowling line was only revealed to have a significant effect in the secondary analyses when the playing surface was divided into smaller zones. Of all variables analysed, bowling length was revealed in this study to have the greatest impact upon the distribution of power hitting strokes with *medium* effects – all other variables were revealed to have *small* effects. The handedness of the bowler nor the competition format had any significant association with ball-hitting distributions in elite-level cricket according to the results of this study.

The primary analysis revealed that shorter pitched bowling resulted in greater than expected 6-run scoring strokes behind square. Corresponding results were discovered in the secondary analysis where greater than expected 6-run scoring strokes were performed in ZONE 1, the 120° arc behind the wicket-keeper. Previous research has revealed that the short-pitched delivery is the least effective wicket-taking delivery (Najdan et al., 2014), however bowlers often tend to bowl it as a means of intimidating the batter by targeting the upper body (Kendall & Lenten, 2017). The results obtained in this study suggest that batters are responding to the short-pitched delivery with deliberate and controlled shots behind square of the wicket. Previous research has revealed that short bowling lengths that pitched 8+ metres away from the batters' stumps elicited an initial back-foot movement by the batters (Pinder et al., 2012). Therefore, the results of this study suggest that batters are successfully executing shots such as the "hook" and "late cut" shots (Khan et al., 2017). Both of these strokes are back-foot shots that enable the batter to judge the trajectory of the ball (Khan et al., 2017). The hook shot in particular is a common response from a batter to a short pitched delivery bowled by a pace bowler (O'Donoghue, 2016). Both of these shots are considered high risk, for poorer performance outcomes (R. A. Stretch et al., 2000) as they require batters to play across the line of the ball, often with a near horizontal bat (Khan et al., 2017). This additional risk demonstrated by batters could be partly due to modern day *limited overs cricket* necessitating greater urgency for attacking play and run scoring strokes (Scanlan et al., 2016). Results also revealed that bowling the half-volley length resulted in greater than expected 6's in ZONE 2, representing the off-side. This finding does correspond with that of previous research that has discovered the half-volley length to be particularly susceptible to power-hitting strokes (Taliep et al., 2010). Furthermore, in their study on the existence of monostable/metastable zones for batters in cricket, Pinder et al. (2012), discovered fuller bowling lengths between 2.5 and 3.5 metres away from the batters stumps elicited a primary forward movement from opposing batters. In addition, fuller bowling lengths have been revealed to encourage front foot attacking strokes such as the "drive" (Chris Peploe et al., 2014; Connor et al., 2020; Sarpeshkar & Mann, 2011). This particular stroke is frequently played in-front of square, to an over-pitched bowling delivery and is one of the most common shots to be performed (R. Stretch et al., 1998). It should be noted that balls that pitched on the "yorker" length (approx. 0–2 metres away from the batters' stumps) did not result in any 6-run scoring shots across the two tournaments analysed in this study (explaining why this length was not represented in the corresponding contingency table). This reinforces the findings of previous research that the yorker length is generally regarded as being the hardest length for batters to strike (Moore et al., 2012).

Bowling line was also revealed to significantly affect the ball distribution of 6-run scoring power strokes, but only in the secondary analyses. Interestingly, only bowling deliveries outside of the line of the three stumps (off, middle and leg) were revealed to significantly affect ball distribution. Previous research with a focus on the accuracy of bowling deliveries has revealed that bowling within the line of the stumps can restrict a batter's ability to score runs (Phillips et al., 2012). In their study, Phillips et al. (2012) regarded both the base and the top of the off stump as ideal targets for bowlers to aim for. Similarly, three out of five targets in a study by Feros et al. (2013) were situated at the top of each stump, with a fourth target halfway up the middle stump. The results of the bowling line variable also revealed ZONE 2 to be of particular interest. Specifically, bowling with "outside-off" lines resulted in greater than expected 6-run strokes in this region on the off-side. This is likely due to the off-side line encouraging off-side shots such as the drive strokes detailed above as well as the "square cut" also frequently played on the off-side (Khan et al., 2017). Fewer than expected 6's in ZONE 2 were scored with bowling deliveries of a "down-leg" line. This is perhaps to be expected, as the down-leg line would take the ball away from ZONE 2.

The type of bowler also affected ball distribution, with fast bowlers being struck for greater than expected 6's behind square. These results conform with previous findings that pace on the ball allows batters to accumulate runs behind the wicket, particularly if they are capable of re-directing the ball and thus using the bowler's speed of delivery to their advantage (Renshaw & Holder, 2010). Another potential reason why fast seam bowling may be susceptible to power hitting strokes behind square, could be due to modern day batters more frequently performing innovative shots such as the "ramp shot" (Portus & Farrow, 2011) or, the "Dilscoop" (Dixit, 2018; Mann & Dain, 2013). Both the ramp and the dilscoop are aerial (often premeditated) shots, which target the vacant area behind the wicketkeeper and slip fielders (Mann & Dain, 2013). The creation of such strokes has been due partly to the emergence of T20 cricket, which has led to batters learning new techniques in order to score faster (Edgar, 2020).

Finally, greater than expected 6's were struck within the powerplay overs. These results suggest batters are taking more risks in the powerplay overs, which have been known to result in a greater number of runs scored on average as well as a greater number of wickets, since their implementation (Silva et al., 2015). Furthermore, this result may be indicative of modern batting strategies of maximising run scoring opportunities in the powerplay, particularly as boundary strokes are riskier to perform in non-powerplay overs due to the greater number of fielders guarding the boundary (Jamil et al., 2021; Najdan et al., 2014).

This study provides evidence that bowlers are at least partly responsible for the ball-hitting distribution of the batter, specifically through the line and length of their delivery as well as their bowling style. Other factors outside of the bowler's control, such as the enforced fielding restrictions caused by powerplays, can also influence the direction in which the ball is played. These results therefore offer some practical implications which could be considered by both batters and bowlers. Given that previous research has revealed the short ball to be the least effective wicket taking delivery (Najdan et al., 2014) and this study reveals that the short ball offers 6-run scoring opportunities to the batter, bowlers may wish to limit their use of the short-ball as an effective bowling delivery in *limited overs cricket*, at least when it is used in isolation. Some research suggests certain types of bowling can be used effectively over a series of deliveries as a means to eventually induce a false shot from a batter (O'Donoghue, 2016), however the use of the short pitched ball to this effect in *limited overs cricket* requires further research. Furthermore, bowlers could look to bowl in line with the stumps and restrict the width offered to batters on the off-side as bowling outside the line of off stump has been revealed in this study to offer 6-run scoring opportunities. It should be noted that variations in pace, line and length do offer strategic advantages (Justham et al., 2010), therefore bowling off-side lines should not be completely disregarded by bowlers as they need to maintain some unpredictability. Similarly, batters should look to take advantage of the powerplay overs and attempt aerial power-hitting strokes whilst the boundaries are less protected. In addition, batters should continue to attack the short ball length and the half-volley length and when doing so target the areas behind square or on the off-side to maximise their 6-run scoring opportunities. Similarly, if offered width with the outside off line then batters could be encouraged to perform off-side shots for potential 6-run scoring opportunities.

This study did have some limitations. Firstly, no data were available on weather conditions, which can impact levels of swing and spin for bowlers (Jamil et al., 2021; Petersen, 2017; Scobie et al., 2020) and thus potentially impact the batters' striking abilities. Second, information regarding whether the ball was delivered by the bowler from over the wicket or around the wicket was also lacking and this alteration of bowling angles could therefore have also affected the distribution of the ball post batting connection. Similarly, there were no data on the exact speed of the balls bowled, which could potentially have impacted the batter's ability to strike the ball. Lastly, data on the movement of the batters at the crease could also have potentially impacted the present results. Some of the effects of these limitations could have been placated somewhat by the inherent variability of the data set in this study. Whilst the authors of this study have attempted to investigate/control for numerous factors that impact batting/bowling performance, there are other factors that are not controlled for, such as, the specific bowler/batter and stadium attendances. Future researchers should look to expand on this research and incorporate the data referred to above if it is available. Future studies could also investigate ball distribution trends in alternative formats such as test cricket, women's cricket, and the newly conceived "The Hundred" format.

Conclusion

This study revealed that bowling length, bowling line, bowler type (style) and power-plays were all significantly associated with ball-hitting distributions of aerial 6-run scoring strokes. Effect sizes revealed bowling length to have the greatest impact of all variables analysed. Shorter pitched balls, such as the short ball and the back of a length deliveries, resulted in greater than expected 6's behind square. Bowling the half-volley length resulted in greater than expected 6's being scored on the off-side. Greater than expected 6's were scored on the off-side to balls bowled outside the line of off-stump. Fast bowlers conceded greater than expected 6's behind square. Powerplay overs also resulted in greater than expected 6's. This study offers both bowlers and batters insight into their inter-dependencies. The results suggest that shorter pitched bowling as well as the half volley length offer batters greater 6-run scoring opportunities and so bowlers may wish to bowl alternate lengths more frequently and limit their half-volley and short pitched bowling. From a batter's perspective, targeting the short ball, the half-volley or balls bowled wide on the outside off stump line may be recommended if looking to score the maximum 6-runs available. Furthermore, batters should aim to maximise their opportunities to play power-hitting strokes during the powerplay overs as the field restrictions appear to be advantageous.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

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