VARIABILITY OF BALL RELEASE PROPERTIES AND PITCH LENGTH ACCURACY IN CRICKET FAST BOWLING

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Accurate ball pitch length in cricket fast bowling is potentially achieved from a redundant combination of four ball release parameters. Yet, it is unknown how parameter co-variations affect pitch accuracy. This study investigates whether pitch length variance is determined by coordinated ball release parameter co-variability. Twelve fast bowlers performed 18 trials at a target length and ball kinematics were captured from an indoor 3D camera setup. Multi-linear regression analysis showed that the four release parameters accounted for 79% of pitch length variance, where vertical velocity variance accounted for the most variance. When each release parameter was independently shuffled across trials, a pitch length model showed no indication of coordinated co-variability between input parameters. Therefore, pitch length accuracy was achieved by independent control of vertical velocity.

KEYWORDS: pitch accuracy, variability, co-variability, fast bowling.

INTRODUCTION: Attributes of maximum ball release speed and pitch accuracy (i.e., successful attainment of intended ball projection length, or flight range) in cricket fast bowling are advantageous, because this combination leads to batting errors of the opposing team. Ball release speed has been a primary focus of bowling biomechanics research (i.e., Portus et al., 2004; Worthington et al., 2013), while the inter-relatedness of ball release parameters that contribute to pitch accuracy have received less focus (Glazier & Wheat, 2014).
As such, there is a knowledge gap related to pitch accuracy. Bowling accuracy has been investigated whilst exploring performance characteristics between different levels of expertise (Phillips et al., 2012), effect of differing pitch lengths on junior performance (Harwood et al, 2018) and the effects of dehydration on ball speed and accuracy (Devlin et al., 2001). However, no reported studies attempted to investigate how a bowler controls pitch length accuracy. Only Harwood et al. (2018) reported the effect of different pitch lengths on release parameter attributes in children, noting a change in ball release angle explains most of the variance in pitch length.
Therefore, it is currently unknown how fast bowlers minimise variability of ball release parameters to control pitch length accuracy in adults. Indeed, performance variability can be mitigated if contributing elements cooperate (e.g., coordination co-variance of parameters). Phillips and colleagues (2012) noted for task demands such as accuracy, the valuation of technique would provide valuable insights into fast bowling performance. For example, how does a bowler control the inherent variability of a redundant combination of ball release parameters: (i) horizontal velocity (ii) vertical velocity (iii) horizontal position, and (iv) vertical position? There is a gap in the current literature on cricket fast bowling that relates to the effect ball release and velocity on pitch length accuracy. Therefore, this study aims to explore variation and co-variation of these four release parameters and identify the key parameters related to pitch length accuracy.

METHODS: Twelve male fast bowlers (mean ± standard deviation: age 19 ± 1; height 1.87 ± 0.04 m; body mass 82.4 ± 11.5 kg) who were members of the Marylebone Cricket Club University team were tested in accordance with the guidelines outlined by the Loughborough University Ethical Advisory Committee. Each bowler bowled a minimum of 18 good (participant determined) length deliveries captured by an 18 camera VICON MX system (250 Hz, OMG Plc, Oxford, UK) in an indoor cricket specific facility. Forty-two retro-reflective markers were attached to the body as specified by Worthington et al. (2013) and two additional 15 x 15 patches of reflective tape were placed on each hemisphere of the ball. Participant marker data was filtered by using a fourth order low pass Butterworth filter at 15Hz. The global coordinate system z-axis was recorded in the upward vertical direction, the y-axis was defined to run parallel to the long axis of the cricket pitch (middle stump to middle stump), with the positive direction being measured from the batter's end. Ball release was determined as the first visual frame where the selected ball marker exceeds 50 mm of horizontal separation of distance from the virtual landmark. The virtual landmark was created as an expression 20% separation gap between the hand and ball marker. This method was determined as an appropriate measure to obtain ball release after a sensitivity analysis and comparison to the method of Worthington at al. (2013).

Ball flight properties were calculated using simple projectile laws based on constant acceleration (over ten frames post ball release), negligible air resistance and computed within the global coordinate system. Pitch length was calculated from the four ball release parameter inputs of (i) horizontal velocity (Vz); (ii) vertical velocity (Vy); (iii) horizontal position (Py); and (iv) vertical position (Pz). Horizontal and vertical resultant ball release velocity were recorded from the average of 10 frames post ball release. Horizontal position (recorded relative to the middle stump from the bowler's end) and vertical release position (ball height) were also recorded at ball release in the global coordinate system. The equation used to calculate pitch length from a standard 22-yard pitch (20.12 m) was:

$$Pitch\ Length = 20.12 - \frac{\left(-Vz - \sqrt{Vz^2 + (2 \times 9.8 \times Pz)}\right)}{-9.8} \times Vy - Py$$

Box plots of ball release parameters and pitch length for the bowling group were used to describe normal distribution of results (Figure 1). Mean pitch length was assumed to represent their goal pitch length and standard deviations were calculated as estimates of bowler variability. The first 18 trials per bowler were used to determine accuracy and ball release parameter values, with an additional ball added in place of any identified outlier trial. Outliers were determined by conducting a Grubbs' test.

Matlab v.2021a (The MathWorks Inc., Natick, MA, USA) was used to complete a cyclical simulated release parameter shuffle, whereby each parameter's individually recorded value was cyclically shuffled 18 times for each of the 18 deliveries. The other release parameter values remained un-shuffled. This shuffle determined the random pitch length variability contribution (standard deviation) of each parameter. Index of Cooperation as used by Kusafuka et al. (2021) was then adopted to indicate parameter co-variability. IBM SPSS Statistics v. 27 (IBM, Armonk, NY, USA) was used to perform a multi-linear regression analysis to explain pitch length variability (dependent variable). The percentage of variance in the dependent variable explained by the independent variables within the regression equation was determined by the R2 value. P-value of <0.05 was used to determine significance of the regression model and independent variables in describing variance of the dependent variable.

RESULTS: Group average pitch length mean, and group average standard deviation was 6.12 ± 1.89 m. Mean vertical velocity variability (1.11 $m \cdot s^{-1}$) was greater than horizontal velocity (0.81 $m \cdot s^{-1}$). However, mean vertical position variability (0.02 m) was less variable than the mean horizontal position variability (0.14 m).

A multi-linear regression model successfully predicted pitch length variance from four ball release parameters (F (4, 7) = 6.55, p = .016, R2 = .789). Of the four predictor variables investigated, only vertical velocity variability (β = 1.313, t-(7) = 4.437, p < .05) was significant.

The surrogate data set and output of modelled (cyclical shuffle) pitch length found that pitch accuracy was not significantly more (or less) variable than random variance of model input parameters (± 1.89 m: After shuffling the model inputs (ball release parameters) across trials the average pitch length variance was 1.90 m for vertical velocity, 1.91 for horizontal velocity m, 1.88 m for vertical position, 1.90 m for horizontal position, and 1.88 m for the horizontal/vertical velocity double shuffle). In support, an Index of Cooperation (IC) revealed a lack of co-variability on pitch length variance (vertical velocity 1.00, horizontal velocity 1.01, vertical position 0.99, horizontal position 1.01, and vertical/horizontal velocity 1.00).

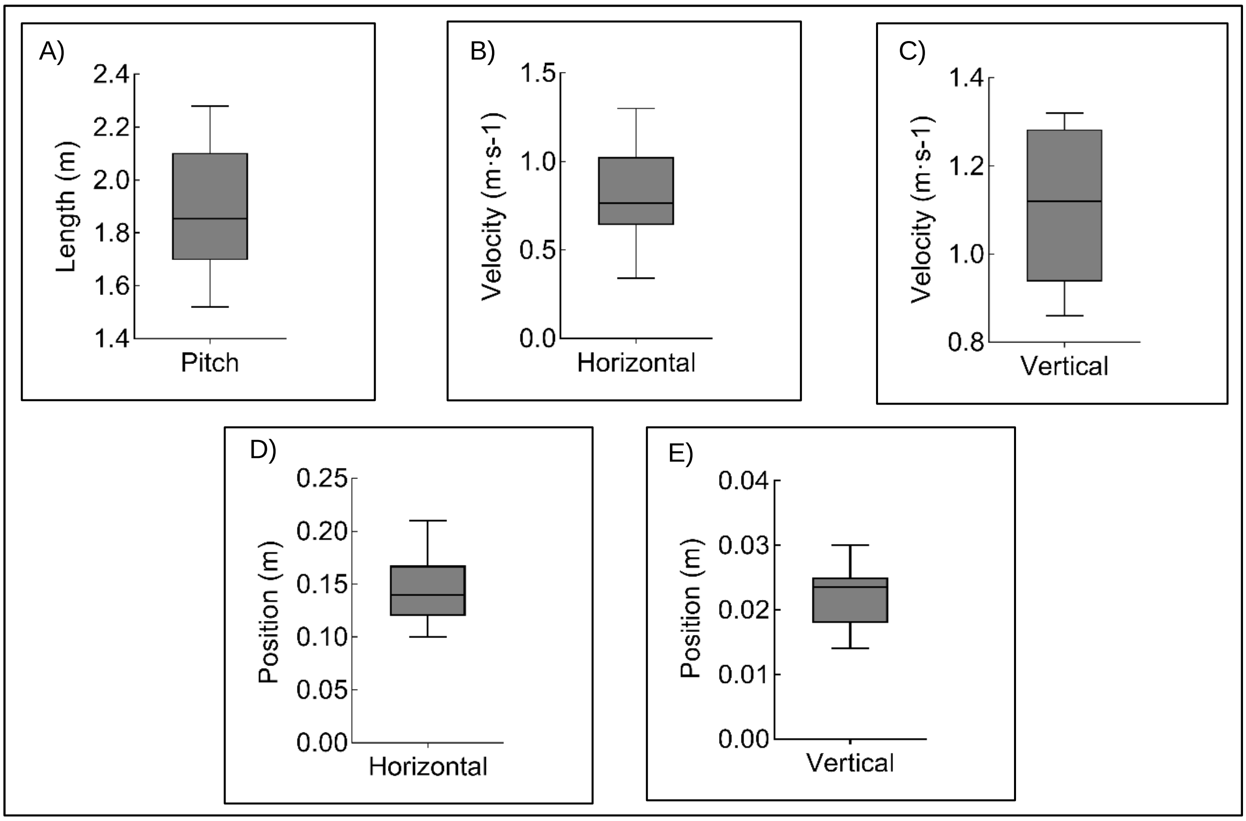

Figure 1: Box and whisker plots showing the group median and quartile distribution: a) pitch length standard deviation b) horizontal velocity standard deviation c) vertical velocity standard deviation d) horizontal position standard deviation, and e) vertical position standard deviation.

DISCUSSION: This study quantified the impact of the four ball release parameters on pitch length variability. Group accuracy was found to be (1.89 m) which was only slightly less accurate than data collated by Cork et al. (2012) (1.76 m). The most variable ball release parameter was found to be vertical velocity which varied by (1.11 m·s-1) amongst the bowling group. Release position standard deviation in contrast varied much less (horizontal position 0.14 m, vertical position 0.02 m) and was comparable to results gathered by Cork et al. (2012) with a horizontal position standard deviation of 0.27 m and Salter et al. (2007) with a vertical release position of 0.03 m. The four ball release parameters were then run through a multi-linear regression. Horizontal velocity variability, vertical velocity variability, horizontal release position variability and vertical release position variability, together explained 79% of the variance in pitch length. Vertical velocity variance was found to significantly describe pitch length control. This result was not unexpected, as Kusafuka et al. (2021) and Harwood et al. (2018) both noted ball release angle played a role in explaining baseball pitching accuracy and cricket bowling pitch length. However, the lack of significance of other parameters suggests vertical velocity is the prominent predictor and influencer of pitch length control. Thus, for bowlers to bowl an accurate length reducing vertical velocity appears to be important.

The lack of evidence indicating ball release positioning's influence on pitch length variability too was not unexpected, because they are deemed as constrained variables. Vertical release positioning is constrained by the physical height of the bowler and any fluctuations in the magnitude have a very limited influence on flight time and range, as demonstrated in underarm throwing by Dupuy et al. (2000). The horizontal release position is also constrained by the bowling crease, whereby the magnitude only varied by 0.14 m in the group, delivering the ball 1.65 m from the bowler's stumps or almost exactly over the bowling crease at 1.6 m. Harwood

et al. (2018) noted junior bowlers showed no indication of adaptive change of their foot position when bowling different lengths and the small change in release position of 0.14 m in this dimension supports that result.
However, it was the lack of evident coordinated co-variation between the release parameters that was the most intriguing result. Index of Cooperation results (vertical velocity 1.00, horizontal velocity 1.01, vertical position 0.99, horizontal position 1.01 & vertical/horizontal velocity 1.00) showed no indication of cooperation between any of the release parameters, as there was no distinct difference in Index of Cooperation scores. Index of Cooperation scores should be regarded as an expression of cooperative contribution to the degree of variability (Kusafuka et al., 2021), and a score close to one poses no distinction between the performed and simulated cyclical results. Thus, the results from this shuffle demonstrate very little if any cooperation is occurring to reduce pitch length variability. Kusafuka et al. (2021) found similar results in baseball pitching vertical displacement, whereby scores close to one were likely due to their limited impact on pitch location. This likely indicates, as with baseball pitching, bowling pitch length accuracy is highly influenced by vertical velocity variability and that pitch variability is unlikely to be adapted or controlled through coordinated co-variation.

CONCLUSION: This study aimed to investigate how cricket fast bowlers controlled their pitch length accuracy from the variability of four ball release parameters. There was found to be little coordinated co-variability amongst the release parameters in reducing pitch length variance. This indicates the release parameters work independently from each other, with vertical velocity having the largest impact on pitch length variance. Therefore, reducing vertical velocity variability is advantageous in improving pitch length accuracy and, as such, understanding how the bowler controls vertical velocity variability should be of focus moving forward.

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