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Run faster, bowl faster: In-match analysis of elite female cricket pace bowlers

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ABSTRACT

Pace bowlers who release the ball at a higher velocity have been shown to both reduce the scoring ability of batters and dismiss batters more often. Run-up velocity is a key parameter consistently shown to influence ball velocity in male pace bowlers, however this has yet to be evaluated in female pace bowlers who have different anthropometric characteristics, strength, and bowling biomechanics. The aim of this study was to analyse in-match global positioning system (GPS) unit data and ball velocity data to determine whether characteristics of the run-up and delivery stride were associated with ball velocity in elite female pace bowlers. Wearable device (gyroscope, accelerometer, and GPS) data and ball velocity data were collated from 28 elite female pace bowlers participating in a T20 competition. Linear regressions were conducted on 1050 bowling deliveries for both absolute ball velocity (raw data) and relative ball velocity (percent of individual's maximum). Univariate analyses found absolute ball velocity was strongly associated with run-up distance ($p = 0.002$), average run-up velocity ($p = 0.010$), maximum run-up velocity ($p < 0.001$), maximum velocity during delivery stride ($p < 0.001$), peak resultant acceleration ($p = 0.013$), and peak roll ($p = 0.031$). Relative ball velocity was most strongly associated with maximum run-up velocity ($p = 0.004$) and maximum velocity during delivery stride ($p < 0.001$). Multivariate analysis found absolute ball velocity was strongly predicted by maximum velocity during delivery stride ($p < 0.001$), peak resultant acceleration ($p = 0.003$), run-up distance ($p = 0.008$), and peak roll ($p = 0.043$). Bowlers should aim to increase their run-up velocity, particularly during the delivery stride, to increase ball velocity. However, this should be in the context of individual factors such as biomechanics and strength.

1. Introduction

Pace bowlers are integral to a cricket team's performance (Johnstone et al., 2014). Pace bowlers who release the ball at a higher velocity have been shown to both reduce the scoring ability of batters and dismiss batters more often (Malhotra & Krishna, 2017). This is attributed to batters having less time to position their body effectively to play a shot (Müller et al., 2009). As such, much attention for pace bowling performance has been directed at increasing ball velocity. To date, research in this area has focused on anthropometric characteristics, strength, and biomechanics in male pace bowlers.

Anthropometric characteristics may influence ball velocity. Taller bowlers have the advantage of a higher ball release which helps optimise the delivery angle, bounce off the pitch, and force production assisting greater ball velocity (Johnstone et al., 2014). Elite male bowlers are heavier and carry more lean mass than junior representatives (Pyne et al., 2006). Larger chest girth and lower skinfold measures have been associated with increased ball velocity in male amateur level cricketers (Portus et al., 2000).

Strength and power are likely to influence ball velocity, although research in this area is limited and findings have not been consistent across studies (Feros et al., 2019; Kiely et al., 2021; Pyne et al., 2006; Ramachandran et al., 2021). Force production from the upper body may positively influence technique and has

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been reported to account for 36-45% of variance in ball velocity (Ramachandran et al., 2021). Elite male bowlers were shown to be more powerful in bench press throw and deltoid throw performance than junior bowlers (Pyne et al., 2006). In sub-elite (local club level) male cricketers, 1-repetition maximum pull-up strength, a measure of upper body pulling strength, correlated with both mean and peak ball release velocities (Feros et al., 2019).

Several biomechanical factors have also been identified which are associated with faster bowling velocities. A more extended front knee during the front foot contact phase of the delivery (Portus et al., 2004; Portus et al., 2000) and a maximum hip shoulder separation angle which occurs later in the delivery stride (Portus et al., 2004) are associated with faster ball velocities. The larger hip shoulder separation angle creates a slingshot like effect during the bowling action. Faster bowlers also display higher braking and vertical impact forces (Portus et al., 2004).

Anthropometric, strength, and biomechanical factors may influence ball velocity, however a recent meta-analysis by Ramachandran et al. (2021) found run-up velocity to be the parameter most strongly correlated with ball velocity. The eight studies which contributed to this finding included six sub-elite-to-elite male cohorts, with correlation coefficients between 0.499-0.737 (strong) (Ferdinands et al., 2010; Glazier et al., 2000; Glazier & Wheat, 2014; King et al., 2016; Middleton et al., 2016; Salter et al., 2007). Interestingly, one study that included an amateur cohort (Middleton et al., 2016) and another study on competitive club-level bowlers (Feros et al., 2019) did not find similar correlations. Three additional studies not included in the meta-analysis also studied high-level bowlers and found strong correlations between run-up velocity and ball velocity (Duffield et al., 2009; Kiely et al., 2021; Worthington et al., 2013). These findings highlight the importance of run-up velocity in high-level male pace bowlers. To date, no studies have analysed whether similar correlations exist with female pace bowlers. Limited research on elite female pace bowlers has shown that their run-up speed is similar to (Savage & Portus, 2002) or slower than (Felton et al., 2019) elite male pace bowlers, with slower ball velocity.

Considering that female pace bowlers have different anthropometric characteristics (Stuelcken et al., 2007), bowling biomechanics (Felton et al., 2019), and likely strength and power (Bartolomei et al., 2021) compared to male pace bowlers, it follows that factors contributing to ball velocity may be different in female bowlers and needs to be researched. A limitation of previous studies in male pace bowlers is that all but one of the previous studies (Salter et al., 2007) used a cross-sectional between-bowler study design, therefore omitting numerous individual factors which may also contribute to ball velocity. A further limitation of these studies is that they were all conducted indoors, with artificial surfaces, indoor shoes, and dimension constraints potentially affecting run-up. All of these factors are likely to produce kinematic results that are different to that of a real world (outdoor in-match) scenario. Therefore, the aim of this study was to analyse in-match data from wearable devices (gyroscope, accelerometer, and global positioning system (GPS)) and ball velocity data over a season to determine whether characteristics of the run-up and delivery stride were associated with ball velocity in elite female pace bowlers.

2. Methods

2.1. Study design

Retrospective cohort study. Ethical approval was obtained from La Trobe University Human Research Ethics Committee (HEC 20058). Individual consent specific to this study was waived given the data was part of routine monitoring.

2.2. Participants

Twenty-eight female pace bowlers competing in the Australian Women's Big Bash League (Twenty-20 (T20) competition) 2019-20 season participated (24.9 ± 5.1 years at the start of the season). Bowlers did not have any injuries which affected their ability to perform as a bowler.

2.3. Run-up and delivery stride characteristics

Bowlers wore a Catapult Optimeye S5 GPS unit (Catapult Innovations, Melbourne, Australia) that was held within a GPS vest worn across the bowlers' upper back. Each unit collected data at 100 Hz. To be included in the study, the bowler's deliveries needed to be auto detected by a bowling algorithm within the Catapult software (Openfield, Catapult Innovations, Melbourne, Australia). For a delivery to be detected, predetermined criteria need to be met across gyroscope, accelerometer and GPS data (McNamara et al., 2015). The algorithm has been shown to be sensitive in training (99%) and competition (99.5%) (McNamara et al., 2015).

Run-up data extracted from the GPS unit included distance, average velocity, maximum velocity, and velocity at the point of delivery. Delivery stride characteristics obtained from the inertial sensors were peak resultant accelerations (obtained from resultant of the peak x,y,z accelerometer outputs), peak roll angular velocity (equivalent to trunk lateral flexion velocity during bowling), and peak yaw angular velocity (equivalent to rotation velocity at the thoracic spine during bowling) (McNamara et al., 2018).

2.4. Ball velocity

Ball velocity was captured during televised matches via a mounted radar gun (Stalker Pro II, Stalker Sports Radar, Piano, Texas) positioned on a tripod outside of the boundary and behind the bowler's arm. This data was coded by the analyst from each of the teams using specialist software (Fair Play Sports Analysis Systems, Fair Play Pty Ltd, Jindalee, QLD) and subsequently uploaded to a central Athlete Management System (Fair Play AMS Pty Ltd, Jindalee, QLD).

2.5. Strength and power

Measures of bench pull (upper body pulling strength) (Bilsborough et al., 2015), counter-movement jump test (lower body power) (Yingling et al., 2018) and isometric mid-thigh pull (lower body pulling strength) (McGuigan & Winchester, 2008) were included as covariates in analyses to control for the potential confounding factors of strength and power. These measures are routinely completed in a standardised manner throughout the season and recorded in the Athlete Management System. The best performance during the season was included in analyses.

2.6. Statistical approach

Absolute ball velocity (raw data) was converted to a percent of the individual's maximum ball velocity recorded in the data set (relative ball velocity). Relative ball velocities ranged from 66-100%, median 93% and interquartile range 90–96%. Lower velocity deliveries were likely the result of the bowler deliberately varying their run-up and delivery to tactically deliver a slower ball. To avoid potential bias of slower deliveries, the lower quartile of deliveries was excluded (i.e., cut off 90%).

Descriptive statistics (mean and standard deviation) were calculated for ball velocity and run-up metrics. Linear regression was used to evaluate the relationship between ball velocity (dependent variable) and delivery characteristics (independent variables): delivery run-up distance, average run-up velocity, maximum run-up velocity, maximum velocity during delivery stride, peak resultant, peak roll, and peak yaw. Data did not satisfy the Shapiro-Wilk assessment of normality (all $p < 0.001$), however from visual inspection of frequency histograms and inability to improve normality of the data with transformation, it was deemed satisfactory to assume normality for analyses. Generalised estimating equations (GEE) with a linear model and exchangeable correlation structure were used to account for repeated measures within individuals. Univariate analyses for each run-up and delivery stride variable were conducted for both absolute ball velocity (raw data) and relative ball velocity (percent of individual's maximum). Absolute ball velocity was modelled with the covariates of age and strength and power characteristics (bench pull, vertical jump, mid-thigh pull) controlled for. Variables with a p-value <0.05 from univariate analyses were included in multivariate analyses, excluding collinear variables determined by collinearity diagnostics. Analyses were performed using SPSS (Version 25.0. Armonk, NY: IBM Corp.).

3. Results

A total 1050 bowling deliveries for the 28 bowlers were included in analysis. The mean number of included deliveries per bowler was 47 ± 24. Mean maximum absolute ball velocity recorded for the season was 113 ± 6 km/h. Mean average run-up distance, average run-up velocity, maximum run-up velocity, and maximum velocity during delivery stride recorded for each bowler across the season were 14.2 ± 3.0 m, 4.5 ± 0.3 m/s, 6.0 ± 0.5 m/s, and 5.4 ± 0.4 m/s respectively. Mean best performances for bench pull and mid-thigh pull (both normalised for body weight), and vertical jump were 3.94 ± 0.43, 0.86 ± 0.12, and 49 ± 6 cm respectively.

Univariate analyses found that run-up velocity metrics (all $p \leq 0.010$), run-up distance ($p = 0.002$), and peak resultant acceleration ($p = 0.013$) strongly predicted absolute ball velocity (Table 1). Age (B = 0.037, 95% CI -0.392–0.465, $p = 0.867$), and bench pull ($R^2 = 0.054$), vertical jump ($R^2 = 0.107$), and mid-thigh pull ($R^2 = 0.002$) for the season did not independently explain the variance in absolute ball velocity. Bench pull, vertical jump, and mid-thigh pull did not predict run-up velocity metrics (all $p > 0.05$), with the exception of bench pull and maximum run-up velocity ($p = 0.039$).

Multivariate analysis for absolute ball velocity included run-up distance, maximum velocity during delivery stride, peak resultant acceleration, and peak roll (average run-up velocity and maximum run-up velocity were collinear with maximum velocity during delivery stride). Absolute ball velocity was strongly predicted by maximum velocity during delivery stride (B = 1.7358, 95% CI 1.019–2.457, $p < 0.001$), peak resultant acceleration (B = 0.387, 0.128–0.647, $p = 0.003$), run-up distance (B = 0.441, 0.116–0.766, $p = 0.008$), and peak roll (B = 0.002, 0.000–0.003, $p = 0.043$).

Average run-up velocity ($p = 0.027$), maximum run-up velocity ($p = 0.004$), and maximum velocity during delivery stride ($p < 0.001$) strongly predicted relative ball velocity (Table 1). Due to collinearity of average run-up velocity and maximum run-up velocity with maximum velocity during delivery stride for relative ball velocity, only maximum velocity during delivery stride met the inclusion criteria for multivariate analysis and hence multivariate analysis for relative ball velocity was not conducted.

4. Discussion

Run-up velocity is an important and modifiable factor contributing to ball velocity in pace bowlers (Ramachandran et al., 2021), however prior to this study the relationship between the two had not been investigated in female pace bowlers in the literature. This study analysed in-match data across a cricket season and found a positive association between ball velocity and: average run-up velocity, maximum run-up velocity, and maximum velocity during delivery stride. Furthermore, analyses controlled for individual factors of age and strength/power, supporting the idea that the faster a bowler runs up, the faster they are able to bowl relative to their own capacity.

The findings from this study suggest that an individual increasing their maximum run-up velocity and maximum velocity during delivery stride by 1m/s will result in the ball being delivered approximately 1km/h faster. However, it is misleading to conclude that bowlers should solely train to improve their sprint velocity to bowl faster. Faster sprint velocity does not necessarily translate to faster run-up and in turn faster ball velocity (Kiely et al., 2021). Each individual bowler is likely to have an optimum run-up speed, beyond which ball velocity and accuracy are compromised (Bartlett et al., 1996; Worthington et al., 2013). Elite male T20 pace bowlers have been shown to have a run-up velocity which is close to their maximal sprint velocity (Sholto-Douglas et al., 2020). Further research is needed to understand what percentage of maximum velocity female pace bowlers typically operate at, and whether this can be manipulated to optimise ball velocity.

Table 1: Relationship between run-up and delivery stride characteristics and absolute (raw data) and relative (percent of individual's maximum) ball velocity. Data presented with 95% confidence interval. N=1050 deliveries included for 28 bowlers.

Run-up and delivery stride characteristics	**Absolute ball velocity (km/h)**		**Relative ball velocity (%)**	
	Slope (B)	*p*-value	Slope (B)	*p*-value
Run-up distance (m)	0.523 (0.193–0.852)	0.002	0.022 (-0.085–0.129)	0.690
Average run-up velocity (m/s)	1.815 (0.425–3.205)	0.010	0.886 (0.101–1.671)	0.027
Maximum run-up velocity (m/s)	2.497 (1.217–3.776)	<0.001	1.109 (0.360–1.859)	0.004
Maximum velocity during delivery stride (m/s)	1.916 (1.025–2.807)	<0.001	1.013 (0.480–1.547)	<0.001
Peak resultant acceleration (m/s^2)	0.448 (0.095–0.800)	0.013	0.194 (-0.012–0.401)	0.065
Peak roll (deg/s)	0.002 (0.000–0.004)	0.031	0.001 (0.000–0.002)	0.052
Peak yaw (deg/s)	0.001 (-0.001–0.002)	0.339	0.001 (0.000–0.002)	0.132

For sprint velocity to translate to bowling run-up velocity, the bowler must firstly be able to maintain run-up velocity into the delivery stride. Secondly, the bowler must then transfer linear momentum from the run-up to angular momentum of the delivery which requires a high braking ground reaction force and coordinated strength to effectively decelerate the body (Callaghan et al., 2021; Ferdinands et al., 2010). It has been postulated that elite female pace bowlers may adopt a slower run-up velocity to allow for controlled execution of the bowling action to account for the likely lower relative strength compared to their male counterparts (Felton et al., 2019), however this has not been researched. Whilst strength may be a factor between sexes, the variable strength between the female pace bowlers in this study did not clearly explain run-up velocity.

Elite female pace bowlers may compensate for a slower run-up velocity with increased pelvis and shoulder rotation compared to male counterparts (Felton et al., 2019). Trunk lateral flexion, measured as peak roll (McNamara et al., 2016), may contribute up to 13% of final ball release velocity (Bartlett et al., 1996). Trunk lateral flexion may be higher in bowlers with a side-on action where the non-bowling arm has a faster path (extension and adduction) compared to bowlers with a more front on action. As such, front-on bowlers may rely more on run-up velocity to generate pace on the delivery (Kiely et al., 2021; Ramachandran et al., 2021). Therefore, individual bowling actions may dictate the relative importance of run-up velocity and delivery stride characteristics. Bowling biomechanics were not included in this study, hence future research and individual assessments should include both run-up velocity and bowling biomechanics to assess their relative importance. Future research should also control for bowler height and lean mass which is a limitation of this study.

The strength of this research being in-match data for ecological validity is at the expense of a lack of control over extraneous variables such as match situation and fatigue. Due to the nature of T20 cricket, players vary their pace, line and length more often than in other formats of the game. Whilst absolute slower balls were excluded from the data analysis, small deliberate changes in pace will still have been captured and analysed against run-up velocity. The intra-individual analyses may have captured how individuals use run-up velocity and delivery characteristics to vary the ball velocity, whether consciously or not.

Equipment is another likely source of variability in the measure. The fixed radar gun used to measure ball velocity was set up by the broadcast companies, therefore the positioning was unable to be directly controlled for the purpose of this study. The inherent margin of error between GPS units was addressed by ensuring players wore the same unit so that any error was consistent for within-player analysis. The algorithm used to detect bowling deliveries was developed using male pace bowlers and therefore the thresholds may be less sensitive for female bowlers. From cross-checking with match scorecards, it is estimated that 40 (3.7%) deliveries did not trigger the automatic detection. These missed deliveries were bowled at a lower velocity and/or produced less roll (trunk lateral flexion as determined by the Openfield software) during the bowler's action, which were likely deliberate attempts to bowl a slower ball. Such balls may have introduced bias to the study and would likely have been excluded by the lower quartile cut-off.

4.1. Conclusion and future directions

Ball velocity is an important performance metric for pace bowlers. Run-up velocity, particularly maximum velocity during delivery stride, is a key factor associated with ball velocity in elite female pace bowlers. Bowlers should aim to increase their run-up velocity to increase ball velocity, however this should be in the context of individual factors such as biomechanics and strength. To further understand the relationship between run-up and delivery stride characteristics and ball velocity, future research may investigate the contribution of a bowler's anthropometric characteristics, bowling technique, and maximal sprint velocity. Future research should also seek to elucidate the relationship between the aforementioned factors and bowling accuracy, another key component of pace bowling performance. Subjective ratings of effort and qualitative information from bowlers regarding how they try to increase or vary ball velocity may lend to coaching cues to more effectively translate the findings of this research to practice.

Conflict of Interest

The authors declare no conflict of interests.

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