

Footwork Geometry and Bowling Pace: The Impact of Back and Front Foot Angles on Ball Speed

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Abstract

Background: The ability to generate high ball speed in fast bowling is closely linked to the efficient coordination of body movements, particularly those involving the lower limbs during the delivery action. **Aim:** This study investigated the biomechanical factors influencing ball speed among the university-level bowlers, focusing on lower-limb kinematics at key phases of delivery under field-based conditions. **Methodology:** A total of 30 male bowlers between 18 and 24 years of age participated in the study, producing 180 analyzed deliveries. Anthropometric data were collected, bowling actions were recorded using high-speed two-dimensional video capture, and ball speed was measured by using a pocket radar-gun. Recorded video footage was analyzed frame-by-frame by using Kinovea 2025.1.1 motion analysis software to record the knee angle during the ultimate contact of the back foot (Right leg) and front foot (Left leg) before the ball release was measured. **Conclusions:** Overall, the study illustrates the practical value of field-based biomechanical analysis in guiding coaching strategies aimed at improving bowling speed and technical consistency.

Keywords: Ball Speed; Lower-limb mechanics; Front-foot contact; Back-foot contact; Cricket Bowling.

Introduction

Classification of Cricket Bowling Techniques

Bowling is a decisive component of cricket, as it directly contributes to dismissing batters and controlling scoring rates. In longer formats of the game, fast bowlers account for a substantial proportion of wickets and play a key role in dictating match momentum. In limited-overs formats, particularly T20 cricket, fast bowlers are especially influential during the power play and death overs, where accuracy, speed, and variation significantly affect match outcomes. Successful fast bowling is often characterized by consistent line and length, commonly referred to as the “corridor of uncertainty,” which encourages edges, leg-before-wicket dismissals, and mistimed strokes.

Cricket bowling incorporates a wide range of techniques that are broadly divided into pace bowling and spin bowling. Based on their bowling speed, the bowlers are classified as slow, medium, medium fast, fast-medium and fast. The inherent, intellectual potentials and real-time conditions instigate the bowlers to deliver the ball as in-swing, out-swing, reverse

swing, off-cutter, leg-cutter, yorker, slower ball, knuckle and bouncer to get out the batsman or to restrict the run scoring opportunities. **Portus et al., 2004** described that, the bowlers bowl with different action leverage and kinetic chain of speed/turn. Moreover, the techniques are not possible with uniqueness in gripping and releasing the ball. Optimizing bowling technique alongside effective load management can lead to measurable improvements in ball speed while simultaneously reducing injury risk. The bowlers are usually to adopt the varying technique which master the bowler to handle the situation with tactical approach. The bowlers exhibiting the gracefulness in bowling which minimize their technical errors and injury. It primarily depends on the bowlers' acceptable approach run distance, accelerated approach run, dynamic attitude of explosive jump before the delivery, ideal arm rotation, legal landing on popping crease, turning ability of the hips, ball release height and controlled trajectory with wrist snap.

It is Understood from **Bartlett et al., 1996** that, run-up and delivery action are coordinated with able support of multiple muscle groups, **Portus et al., 2004** hip and pelvis movements placing a crucial role for fast bowlers at the moment of back-foot contact, **King et al., 2013** Abdominal and shoulder muscles engages at the bowling occasion of front-foot contact and ball release and **Worthington et al., 2013** described about the momentous contribution of hand muscles and ground reaction force in bowlers' follow-through phase. Ball speed depends upon the lower limb kinematics **Elliott, Foster and Gray, 1993; King, Worthington and Ranson, 2013**.

Purpose and Justification of the Study

Extensive biomechanical research has examined elite fast bowlers using laboratory-based methods, comparatively little attention has been given to average-speed bowlers and within-bowler variability across multiple deliveries under field conditions. This limitation is particularly relevant at the university and sub-elite levels, where players often experience performance plateaus and have limited access to advanced motion-capture facilities. Recent studies demonstrate that two-dimensional video analysis provides valid and reliable measurements of joint angles related to bowling speed (**Panigrahi et al., 2020**), while field-based multi-camera systems can accurately capture angular variables influencing ball velocity, comparable to laboratory-based systems (**Fuss et al., 2021**).

Accordingly, the present study aims to investigate the relationships between lower-limb angular kinematics and ball speed of bowlers. This research could bridge the gap between laboratory biomechanics and practical coaching application. Through this research, the researchers aim to provide actionable insights for training interventions, to explore technical strengths and deficiencies, enhancing speed consistency, and sustain his/her overall performance.

Methodology

Selection of Subjects

The study sample comprised 30 male medium-fast bowlers were selected from Gandhigram Rural Institute (Deemed to be University), Gandhigram (12), GTN Arts College,

Dindigul (5) and Mar Gregorios Arts and Science College, Chennai (10) and The Madura college, Madurai (3) and they were regular participants of organized Cricket tournaments. Bowlers with recent injuries, physical impairments, or ongoing rehabilitation were excluded from this study.

Age, height and weight of the bowlers were assessed a day before the test day. Height was measured to the nearest 0.1 cm using a (EASYCARE, China.) wall mounted manual height measuring scale. Body mass was measured using a calibrated digital weighing scale (SAMSO, India.).

Study Design

To achieve the purpose of the study, 30 right arm medium bowlers were given six delivers to bowl. Entire bowling actions of the bowlers were recorded by using two Redmi Note 14 Pro 5G mobile phones with 30fps and mounted on a tripod at the distance of 10 meters behind from the popping grease and another was 15 meters adjutant to the popping grease. Recorded video footage was analyzed frame-by-frame by using Kinovea 2025.1.1 motion analysis software to record the knee angle during the ultimate contact of the back foot (Right leg) and front foot (Left leg) before the ball release as observed in the figure 1&2.



Figure – 1 Back Foot Contact



Figure -2 Front Foot Contact

Ball Speed

Ball speed (BS) was measured by using a Pocket radar gun (Smart Coach \pm 0.2 km/h, USA) located behind the target board to record the ball speed of every delivery of the bowler.

Data Extraction

Among the 180 deliveries bowled by 30 medium-bowlers, the deliveries of highest (HBS) and lowest ball speed (LBS) of every bowler were separated for analysis. In addition to this, six deliveries bowled by the participants were also considered to evaluate the individual performance and its association with back foot contact (BFC) and front foot contact (FFC) angle. Further a gross-root level of classification was made based on the association between ball speed and BFC & FFC. In that way, the bowlers separated into following ways

1. Positive association between BS and BFC and between BS and FFC group (PPG)
2. Negative association between BS and BFC and positive association between BS and FFC (NPG)
3. Positive association between BS and BFC and negative association between BS and FFC (PNG)
4. Negative association between BS and BFC and between BS and FFC group (NNG)

Results

Descriptive statistics of the participants' age, height, weight and bowlers' HBS, HBS-BFC, HBS-FFC, LBS, LBS-BFC and LBS-FFC are presented in table 1.

Table 1
Descriptive Statistics

Variables	Mean	S.D.	Minimum	Maximum
Age	20.23	1.99	16.00	24.00
Height	174.66	7.03	164.70	196.50
Weight	62.08	9.14	47.35	86.00
HBS	102.22	9.25	77.00	119.00
HBS-BFC	154.13	13.70	127.00	175.00
HBS-FFC	158.20	11.06	140.00	180.00
LBS	91.70	16.22	42.00	113.00
LBS-BFC	151.26	14.05	119.00	174.00
LBS-FFC	156.96	11.31	133.00	179.00

Table 2
 Simple Correlation on HBS, LBS and its BFC and FFC

Variables	HBS-BFC	HBS-FFC	LBS-BFC	LBS-FFC
HBS	0.265	0.038	-	-
LBS	-	-	0.254	0.127

* $r_{(0.05)28} = 0.423$

Correlation analysis revealed that, there was some positive relationships between HBS and HBS-BFC & HBS-FFC. LBS also indicated positive relationships between LHBS and LBS-BFC & LBS-FFC.

PPG of Bowlers' mean (M) and standard deviation (S.D) of BS, BFC, FFC, Coefficient of Variation (CV) on BS, relationship between BS and BFC and between BS and FFC are shown in table 3.

Table 3
 PPG BOWLERS

Bowler	BS	BFC	FFC	CV	r between Ball Speed and	
	M ± S.D.	M ± S.D.	M ± S.D.	BS	BFC	FFC
1	108.50±1.64	163.66±3.20	165.83±5.77	1.51	0.075	0.431
2	116.50±1.97	171.00±2.44	168.00±9.38	1.69	0.206	0.680
3	106.50±1.64	132.83±4.16	160.33±6.68	1.54	0.248	0.746
4	96.00±2.36	148.83±14.70	166.33±1.03	2.46	0.011	0.245
5	107.00±2.09	155.00±6.69	166.66±4.96	1.96	0.242	0.556
6	98.33±2.58	144.66±6.77	166.83±4.99	2.62	0.099	0.222
7	109.16±2.13	170.16±5.45	138.50±6.05	1.95	0.288	0.254
8	87.16±26.28	155.50±4.08	139.83±8.63	30.15	0.187	0.053
CV	5.49	3.90	3.79	5.49		

* $r_{(0.05)4} = 0.811$

From table -3 it is understood that, eight bowlers ball speed have positive association with BFC and FFC.

NPG of Bowlers' mean (M) and standard deviation (S.D) of BS, BFC, FFC, Coefficient of Variation (CV) on BS, relationship between BS and BFC and between BS and FFC are shown in table 4

Table 4
 NPG BOWLERS

Bowler	BS	BFC	FFC	CV	r between Ball Speed and	
	M ± S.D.	M ± S.D.	M ± S.D.	BS	BFC	FFC
1	98.83±3.18	145.16±11.95	166.83±4.49	3.22	-0.219	0.668
2	101.00±1.78	161.83±1.32	142.00±4.64	1.77	-0.588	0.144
3	97.83±1.60	158.00±2.28	157.00±3.52	1.63	-0.656	0.496
4	106.00±2.96	131.66±6.34	137.00±6.16	2.79	-0.201	0.732

5	89.06±3.74	150.83±7.62	174±3.40	4.20	-0.037	0.276
6	91±1.54	153.5±8.50	166.66±2.73	1.70	-0.030	0.850*
CV	2.55	4.32	2.72	2.55	* $r_{(0.05)4} = 0.811$	

From table - 4 it is understood that, the ball speed of the SIX bowlers has negative association with BFC and positive relationship with FFC.

PNG of Bowlers' mean (M) and standard deviation (S.D) of BS, BFC, FFC, Coefficient of Variation (CV) on BS, relationship between BS and BFC and between BS and FFC are shown in table 5

Table 5
PNG BOWLERS

Bowler	BS	BFC	FFC	CV	r between Ball Speed and	
	M ± S.D.	M ± S.D.	M ± S.D.	BS	BFC	FFC
1	109.16±0.98	173.16±3.97	173±3.40	0.89	0.145	- 0.836
2	110.33±3.07	157±7.45	149.83±4.87	2.78	0.174	- 0.489
3	104.5±2.58	136.83±7.52	149.66±3.07	2.46	0.539	- 0.075
4	96±2	157±1.89	160±3.89	2.08	0.158	- 0.026
5	79±0.89	123±6.12	151±5.98	1.12	0.000	-0.598
6	95.73±1.87	155.66±10.48	163.83±3.97	1.95	0.745	-0.567
7	101.60±2.20	165.16±4.95	161.16±2.22	2.16	0.132	-0.488
8	93.06±11.33	161.5±5.00	163.16±4.95	12.17	0.069	-0.235
9	88±3.2	147±7.87	167.33±1.96	3.63	0.368	-0.610
10	96.5±1.22	151.66±3.93	167.16±1.94	1.26	0.623	-0.126
11	89.33±1.96	150.83±8.79	154.50±14.23	2.19	0.108	-0.121
CV	2.97	3.94	2.77	2.97	* $r_{(0.05)4} = 0.811$	

From table - 4 it is understood that, the ball speed of the Eleven bowlers has positive association with BFC and negative relationship with FFC.

NNG of Bowlers' mean (M) and standard deviation (S.D) of BS, BFC, FFC, Coefficient of Variation (CV) on BS, relationship between BS and BFC and between BS and FFC are shown in table 5.

Table 5
NNG BOWLERS

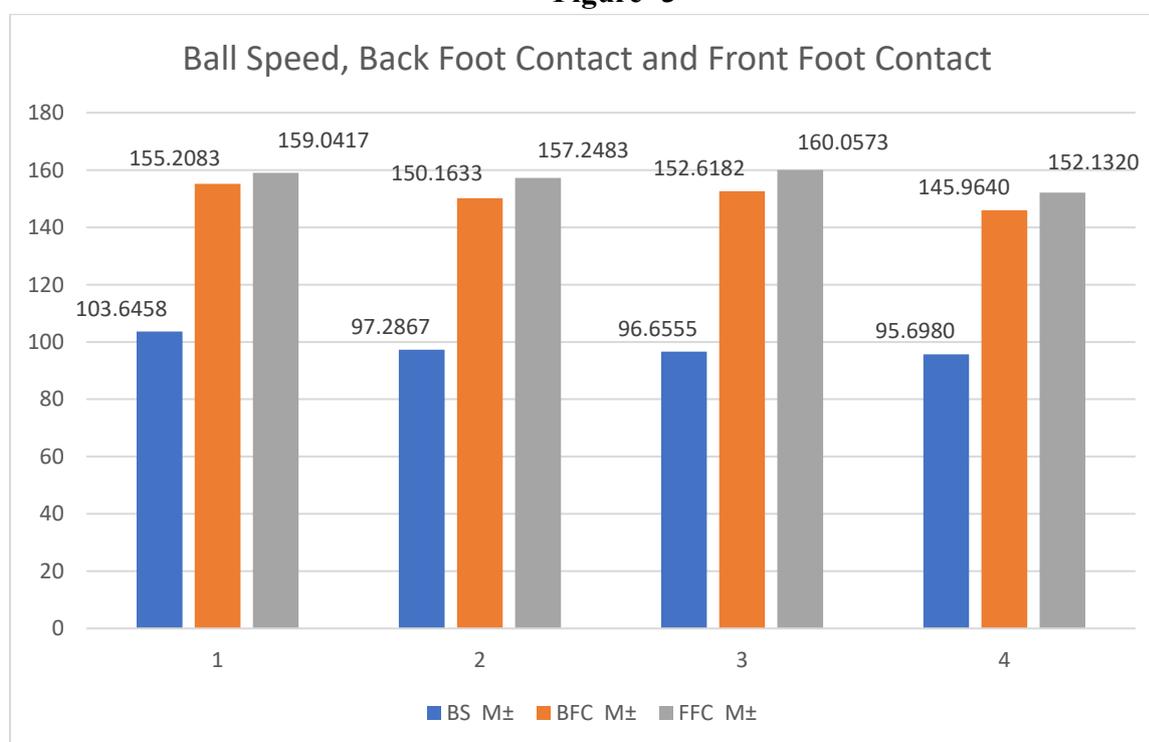
Bowler	BS	BFC	FFC	CV	r between Ball Speed and
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	M ± S.D.	M ± S.D.	M ± S.D.	BS	BFC	FFC
1	104.5±2.73	171.33±4.67	162.00±2.68	2.61	-0.203	-0.163
2	74.83±1.94	154.50±7.14	156.50±3.50	2.59	-0.800	-0.631
3	103.00±1.83	133.16±4.07	156.83±5.41	1.77	-0.112	-0.278
4	104.16±7.46	141.83±4.02	138.33±7.28	7.16	-0.172	-0.152
5	92.00±21.58	129.00±3.79	147.00±5.65	23.45	-0.388	-0.565
CV	7.52	3.64	3.61	7.516	*$r_{(0.05)4} = 0.811$	

From table - 6 it is understood that, the ball speed of the five bowlers has negative association with BFC and FFC.

Figure -3 presents the ball speed, BFC, FFC measured across six deliveries performed by four groups of medium bowlers.

Figure -3



Discussion on Findings

Fast bowling performance is strongly influenced by lower-limb kinematics, particularly the angles observed at front-foot contact (FFC) and as well as run-up consistency and delivery timing (**Worthington, King and Ranson, 2013**). The result of the present study indicated that, higher ball speed bowlers (103.64) had more BFC (155.20) and FFC (159.04) when compared to the slow ball speed. At the same time slow ball speed bowlers (95.69) had lesser BFC (145.96) and FFC (152.13). Conversely, NPG, noticeable by collapsed angles, resulting in slower deliveries (95.69Km/h). In the category of PNG bowlers' patterns show a mixed ascent; strong BFC support (up to 173.16°) compensates for weaker FFC(149.66°),

maintaining moderate speeds at 96.65 km/h. Increased front-knee extension at FFC enhances ground reaction forces and improves momentum transfer through the kinetic chain, resulting in higher ball release speeds (**Worthington, King and Ranson, 2013**). The bowlers' average height is 174.66 cm, front leg (left) extends variably at FFC (average 158.20°) for braking, while the back leg (right) provides propulsion at BFC (average 154.13°). In a static measurement, the length of the front leg is similar to that of the back leg, but when extended, it appears longer (on average FFC > BFC by about 4°), which enhances the stride. The difference between "one's leg" (presumably the researchers, or front leg) and "his back leg" exemplifies contextual variation e.g., one's back leg at 151° (Lowest Ball Speed) versus the optimal front leg at 158°, this 7° difference underscores the stability difference for generating speed. Conversely, excessive knee flexion at critical phases can disrupt force transmission and reduce bowling velocity. Movement variability across joint angles also affects the consistency of ball speed across repeated deliveries, emphasizing the importance of coordinated inter-segmental motion rather than isolated joint actions. Differences in back-leg drive angles and stride mechanics contribute to variability between faster and slower deliveries.

Salter et al., 2007 studied the bowling techniques by using two methodologies (between-bowlers and within-bowler) and recommended that within-bowler methodology is better to study the technique relationships. In line with the Salter et al., 2007, within-bowler methodology adopted in the present research. In that way, CV of BS with-in bowlers in PPG category had 5.49 and NNG category had 7.51. Similarly, CV of BFC and FFC in PPG, NPG, PNG and NNG is 3.90 and 3.79, 4.32 and 2.72, 3.94 and 2.77 and 3.64 and 3.61 respectively.

Based on the relationship among the bowlers BS and BFC, FFC, depicts into four groups namely PPG, NPG, PNG and NNG across six deliveries of BS, BFC, FFC. Bowler's HBS peaks ~116.5 km/h, likely at optimal angles (BFC 171°, FFC 168°). Bowler's LBS troughs ~74.83 km/h, at suboptimal angles (BFC 154.5°, FFC 156.5°). Bowling performance is influenced by both the speed of the ball and the orientation of the body at the moment of release. The findings of this study revealed a wide range of relationships between lower-limb kinematics and ball speed, indicating that bowling efficiency in average-speed bowlers is highly individualized. Some bowlers demonstrated strong positive associations between front-leg extension and ball speed, while others showed negative or mixed relationships, reflecting differences in technique and movement control. High variability among participants indicated technical imbalances that could potentially be improved through targeted conditioning and movement retraining.

Negative relationships associated with back-foot contact suggested instability during early delivery phases, which may increase mechanical load on the lower back and reduce energy transfer. In contrast, improved front-foot stability and timing were associated with faster recalibration of the delivery action and more efficient force transmission. These findings emphasize the importance of precise lower-limb positioning and sequencing during the bowling action.

Anthropometric differences among the bowlers influenced leverage, balance, and support during delivery. Variations in height and body mass affected the mechanical advantage

gained from the run-up and stride length. Although the total number of deliveries provided a comprehensive dataset, individual comparisons between faster and slower deliveries revealed technical inconsistencies that were masked in group-level analysis. From a methodological perspective, two-dimensional motion analysis proved effective for field-based assessment, though it remains limited in capturing multi-planar movement patterns. Ball speed measurements were consistent and reliable, supporting the validity of the results. Practically, the findings highlight the importance of posture control, optimal front-leg extension, efficient force absorption, and workload management. Small angular adjustments were associated with meaningful improvements in ball speed while reducing injury risk. Future research should focus on advanced motion-tracking technologies, wearable sensors, artificial intelligence assisted feedback, and long-term intervention studies to enhance performance development and durability in competitive Cricket environments.

Overall perspective of the present study implies that, PPG bowlers' FFC is higher than the BFC, very less difference exists between BFC and FFC. Similarly NPG bowlers had big difference between BFC and FFC. As per the BS is concern PPG had high ball speed than the NPG, PNG and NNG bowlers. Based on the previous research and present study exhibits strong positive correlation between FFC and BS. Similarly bowlers' BFC and FFC determined the ball speed in that way PNG and NNG bowlers had very less ball speed. This research relayed the information that the bowlers need a good bowling technique i.e. strong positive association between BFC, FFC and BS.

Conclusion

This study examined the key biomechanical factors influencing ball speed in university-level medium-bowlers, focusing on lower-limb movement and coordination during different phases of delivery. The results show that bowling performance is highly individual, shaped by front-foot stability, back-foot mechanics, approach consistency, and body structure.

Front-leg extension at front-foot contact was found to be essential for maximizing ball speed by improving force transfer through the kinetic chain. Bowlers who maintained stable front-leg positions delivered faster balls, while excessive back-foot collapse or knee bending reduced velocity and efficiency.

Overall, effective fast bowling depends not only on speed but on the combination of biomechanical efficiency, physical attributes, and tactical application. Small adjustments in lower-limb positioning can improve performance while reducing the risk of injury.

Future Directions, Summary

Future research should focus on long-term investigations to better understand how fast bowlers develop and adapt their movement patterns over prolonged training and competitive periods. The use of advanced motion analysis techniques, including three-dimensional systems and wearable sensors, would allow a more comprehensive evaluation of trunk motion, shoulder coordination, and complex joint movements that cannot be fully examined using two-dimensional analysis. Furthermore, predictive models that integrate movement data, physical characteristics, and workload information may assist in forecasting improvements in ball speed

and identifying potential injury risks. Intervention-based studies emphasizing stride mechanics, front-leg stability, and resistance-based throwing drills could strengthen field-based coaching practices and enhance performance consistency in match situations.

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