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A BIOMECHANICAL ANALYSIS OF SPIN BOWLING IN CRICKET

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Abstract:
The main aim of this study was to evaluating the various relationships of the identified biomechanical variables towards the performance of spin bowling and evaluating the contribution of identified biomechanical variables and construction of predictive model. Five interuniversity level leg-spin bowlers were recruited from LNIPE, India, and their bowling actions were captured by three video cameras, in a field setting. A value of $\alpha = 0.05$ was used for all tests as the criterion to determine the presence or absence of significance. Pearson's product moment correlation coefficient (r) was used for evaluating the various relationships of the selected variables towards the performance of spin bowling. Significant relationship was found between the Angle of Release ($r = 0.965$, $P < 0.05$), Average Velocity ($r = 0.541$, $P < 0.05$), Elbow joint Right ($r = -0.392$, $P < 0.05$), Hip Joint left ($r = 0.402$, $P < 0.05$), and Shoulder joint left ($r = -0.383$, $P < 0.05$). Multiple Linear Regression was used for evaluating the contribution of identified biomechanical variables and construction of predictive model. The regression equation was reliable as the value of R^2 was 0.945. The two variables selected in that regression equation explain 94.5% of the total variability in lateral deviation of ball was good. Since F-value for that regression model was highly significant, the model was reliable. This study provides further understanding of the biomechanical variables are associated with skilled performance in cricket leg-spin bowling, which coaches should consider when training less-skilled performers.

Keywords: kinematics, cricket, ball deviation, regression

1. Introduction

Bowling is three key skills in cricket; spin bowling is a more tactical art. Spin bowling plays an integral role within the game of cricket. It is perhaps surprising that the top three bowlers in test match cricket and the top bowler in one-day cricket all being spin bowlers. A spin bowler imparts rotation to the cricket ball, which makes the ball deviate from its original direction of flight when it hits the ground. Spin bowlers attempt to deceive batsmen by deviation of the ball as it bounces off the wicket.

A ball bowled with spin affects the flight and bounce of the ball, making it more challenging for the batsman to play (Woolmer, 2009). Spin can also alter a ball's line of travel upon landing, changing its direction towards the left or right (Daish 1972; Wilkins 1997). Furthermore, in any spinning ball, the vertical component of flight affects the ball's angle of incidence, and therefore the angle of bounce (Woolmer, 2009). the spinning ball in cricket has been studied on ball kinematics in flight and off the pitch (Beach et al., 2012; Spratford and Davidson, 2010), The legality of bowling actions with research focusing on the bowlers technique (Aginsky & Noakes, 2010; Lloyd et al., 2000; Portus et al., 2006), quantifying the measurement differences between video and motion analysis techniques (Elliott et al., 2007), and elbow kinematics (Chin et al., 2009; Lloyd et al., 2005; Ferdinands and Kersting, 2007). Ferdinands et al. (2001) who performed a rigid body model analysis on one spin bowler and Lloyd et al. (2000) who published a case study on the bowling action of Muttiah Muralitharan, providing some quantification to this bowling form; with limited qualitatively based books by Philpott (1973, 1978) and Brayshaw (1978).

Loram et al. (2005) demonstrated that a multiple regression model for schoolboy bowlers based on front knee kinematics and the angle at which peak torque was generated in a bowler's shoulder could be used to predict ball release speed (model R^2 0.85). The coaching manuals generally specify the same set of technical instructions for both off-spin and leg-spin bowling, with only minor differences occasionally stipulated, such as stride length, front knee mechanics, and release position (Cricket Australia, 2005 and 2010). In addition to coaching material from cricket associations currently guiding our understanding of spin bowling, it seems reasonable to suggest that spin bowling in cricket currently resides in the realm of the arts.

However, the success of leg-spin bowlers is not reflected in the scientific literature, with very few peer reviewed journal articles examining on any aspect of leg-spin bowling. A combination of many factors determines success in leg-spin bowling. One of these factors is the deviation of the ball after the pitching. The limited research into the basic mechanisms underlying specifically leg-spin bowling in cricket highlights the need for more information directly applicable to the cricketer. The aim of this study was therefore to identify key mechanical features of leg-spin bowling and to identify the kinematics involved in producing ball deviation of cricket players; firstly, to investigate the relationship of identified biomechanical variables with lateral deviation of ball in leg-spin bowling technique; secondly, to identify the biomechanical variables which contribute significantly towards lateral deviation of ball in leg-spin bowling. Due to the limited amount of research, little is known about how spin is imparted on the ball, or about the influential kinematic movements within the leg-spin bowling action. So, the current study was design to assess the various relationships of the identified variables with the performance of leg spin bowling and the contributions of identified variables towards the deviation of the ball in leg spin bowling and hopefully answered the question of how variables are related with lateral deviation of ball during in leg-spin bowling. The ability to measure the kinematic properties of ball spin will provide coaches with a quantitative assessment of the some of the most important leg-spin bowling performance variables, information that is essential for the provision of objective feedback to bowlers on their performance. And the technical aspect of bowling technique will help player to integrate the technical component of the sports and in so doing invigorate their needed sports skills.

2. Methods

2.1 Participants

Five male leg-spin bowlers were recruited from the cricket academy of Lakshmibai National Institute of Physical Education, India. These bowlers were interuniversity level players at this age bracket (mean ± s: age = 19.0 ± 1.0 years; mean body mass 72.0 ± 9.4 kg; mean height 177.6 ± 8.9 cm). To aid logistics, all bowlers were right-handed. They had represented their top team in the University cricket tournament.

This study was approved by the Research Degree Committee of Lakshmibai National Institute of Physical Education, Gwalior (M.P), India and the participants were provided with an information sheet clearly establishing the benefits from the bowling analysis and their rights as a participant.

2.2 Experimental Protocol

The participants were instructed to undertake a cricket related warm-up activity of their choice. Each bowler was allowed an over (six deliveries) of practice deliveries to aid familiarization with the test environment. An over at maximum effort was then bowled. Each bowler bowled six deliveries and six legitimate (excluding ‘no balls’) and accurate deliveries were recorded for each participant for biomechanical analysis of leg-spin bowling. Trials were conducted in a randomised fashion in order to minimise the likelihood of fatigue affecting one condition more than any of the others. In addition, participants were given the opportunity to take breaks if they began to feel tired at any time. All deliveries were bowled with a standard match Kookaburra ball (mass of 0.156± 0.163 kg and circumference of 0.224± 0.229 m) at marked target areas on the pitch, at a 'good length' (11.5 – 14.5 m from the bowling crease). A successful trial required the ball to land within the marked areas were selected for analysis. The only items of clothing worn were training shoes and sports shorts to facilitate the identification of anatomical landmarks. All subjects underwent the same testing protocol and were injury free at the time of testing. Before the experiment, consent forms were collected. After issuing instructions to the subjects, their body heights and weights were recorded. White stickers (25 mm in diameter) were placed on the subjects bodies at sixteen anatomical joint centres (right and left: toe of boot, ankle, knee, hip, shoulder, elbow, wrist, and index finger knuckle) to facilitate the automatic video image digitization. The shoulder joint centre was estimated using the regression equation of Campbell et al. (2009). The elbow and knee joint centres and axes were estimated using a pointer method (Cappozzo et al., 1995) and along with the hip joints, functional axes were calculated (Besier et al., 2003; Chin et al., 2010).The wrist and ankle centres were defined as the midpoints of lines between markers affixed to the styloid processes of the wrists and the malleoli of the ankles, respectively. For the purpose of the present study, ten independent variables (such as right and left: Ankle Joints, Knee Joints, Hip Joints, Shoulder Joints, Elbow Joints & Wrist Joints, Height of Centre of Gravity at Release, Height of Release, Angle of Release, Average Velocity) were selected to analysis the bowling performance of the bowlers. The performance was recorded on the basis of the lateral deviation of the ball (dependent variable); i.e. the lateral displacement of the ball between the point of landing to the imaginary point of intersection between stump line (bowling crease) and path of ball.

2.3 Biomechanical Assessment

Biomechanical analysis of spin bowling was conducted by capturing the outdoor bowling action trials of each participant on video. Three video cameras (Nikon D-3100, Sony HDR-C-CX200 and Panasonic SDR-H101; 50 frames/second), in a field setting was employed in this study. The camera was set-up on a rigid tripod. Six legitimate (excluding 'no balls') and accurate deliveries were recorded for each participant.

2.4 Camera set-up

First camera (Nikon D-3100) was positioned perpendicular to the sagittal plane and so as that the bowler's arm gives approximately a 90^{o} between their respective optical axes. The distance of the camera from the subject was 5.03 meters away and the height of the lens was 1.00 meters from the ground, so that the motion of subjects on the sagittal plane could be recorded and the purpose of measuring the different joint angles and angle of release of the ball. The second camera (Sony HDR-C-CX200) was positioned on the frontal plane, behind the stumps for measured deviation of ball. The distance of the camera from the stumps (behind) was 2.75 meters away and the height of the lens was 0.95 meters from the ground. For the purpose of measuring the velocity of the ball, and the third camera (Panasonic SDR-H101) was placed on the sagittal plane, perpendicular to the center of the pitch. The distance of the camera from the center of the pitch was 22.50 meters away and the height of the lens was 1.00 meters from the ground (Fig. 1.). A hurdle was filmed prior to filming of subjects for reference of height and distance. The recorded videotapes were digitized and analysed on a motion analysis system (Kinovea Software; 0.8.15).

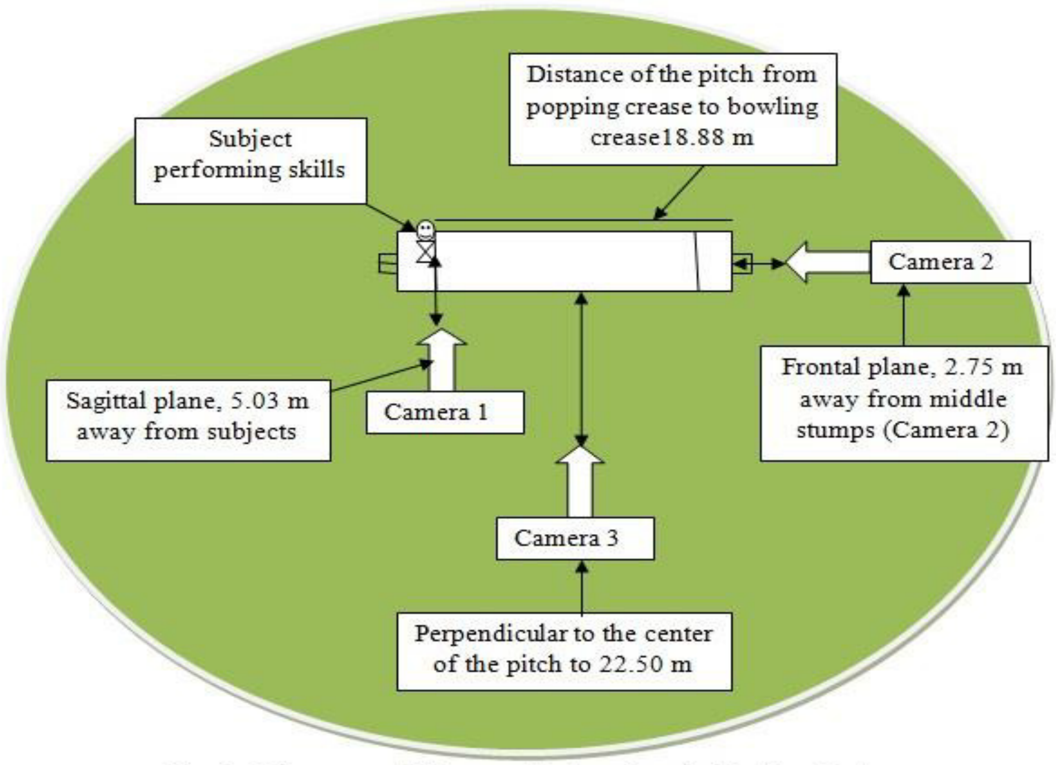

Fig. 1: Diagram of Camera Set-up for Collecting Data

2.5 Data Reduction

After video recording sessions were over, the video recording was loaded into the researcher's personal computer (PC) for trail identification. The identified trails were played with the help of Kinovea software (0.8.15) to make separate clips of each biomechanical variables and ball deviation. The separate clips were then opened on to the Kinovea software. Software was used to measure the angles at different joints (Fig. 2.). Segmentation method was used to measure the Center of gravity at release movement (suggested by James G. Hay, 1978). Ball release height was the vertical distance from the ground to the central core of the cricket ball. Angle of Release of the ball was measured between the path of the ball and imaginary parallel line to the ground (Fig. 3.). Velocity of ball was measured by dividing distance i.e. the distance of 18.90 mt [20.12 mt (total length of the pitch) - 1.22 mt (Popping Crease)] between the two ends of cricket pitch, and the time taken by the ball to travel that distance. For measuring the performance of the subjects (Lateral Deviation of the ball), we recorded all six deliveries with a video camera (Sony HDR-C-CX200, Japan) positioned behind the batsman's stumps. We then used image analysis software (Kinovea software) to measure the ball deviation; point of the pitching of the ball was marked with the mark tool of Kinovea video analysis software and then video was played up to the point of crossing of the bowling crease by the ball, a perpendicular line was drawn from the ball to the bowling crease and perpendicular line was drawn from the previous line, from the point of pitching of the ball, it was calibrated with the stumps height, which provided how much the ball deviate from its original direction? (Fig. 4.)

Fig. 2: Angle of the Joints at the time of Ball Release Moment

Fig. 3: Angle of Release of the Ball

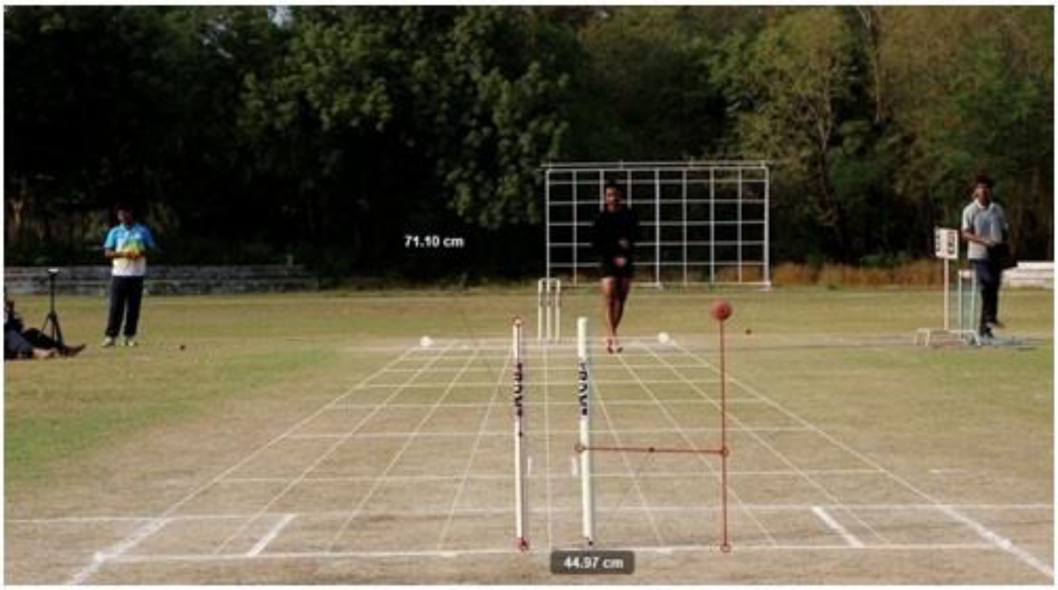

Fig. 4: Lateral Deviation of Ball

2.6 Statistical Analysis

For investigating the raw numerical data collected, they were arranged sequentially, tabulated and subjected to the desirable statistical analysis by using IBM SPSS 20. The data in the study was analysed by using the following statistical techniques. Descriptive analysis statistics was used for describing the data and nature of the data obtained on the samples of the study. Pearson's Product Moment Correlation was used for evaluating the various relationships of the selected variables towards the performance of spin bowling. Multiple Linear Regression was used for evaluating the contribution of identified biomechanical variables and construction of predictive model. A value of α = 0.05 was used for all tests as the criterion to determine the presence or absence of significance.

3. Results

Before discussing the research issues the nature of the variable were analysed through Descriptive Statistics which have been presented in Section A. Pearson's Product Moment Correlation which have been presented in Section B. Multiple Linear Regression analysis which have been presented in Section C.

Section A: Descriptive Statistics for evaluating the nature of the data

To understand the nature of the data various statistics such as Range, Minimum, Maximum, Mean, Standard Deviation, Skewness, Kurtosis, Standard Error of Skewness (SES) and Standard Error of Kurtosis (SEK) has been calculated.

Table 1: Descriptive Statistics of Biomechanical Variables

Variables	Range	Min.	Max.	Mean	S.D	Skewness	SES	Kurtosis	SEK
Height of Center of Gravity	30.40	88.44	118.84	99.81	9.01	.450	.427	-.968	.833
Angle of Release	4.00	8.00	12.00	10.20	1.03	-.024	.427	-.587	.833
Height of Release	42.83	181.02	223.85	199.26	14.05	.495	.427	-1.009	.833
Average Velocity	3.53	12.33	15.86	13.96	1.04	.740	.427	-.270	.833
Ankle Joint right	43.00	88.00	131.00	109.60	12.56	.044	.427	-1.034	.833
Knee Joint right	32.00	115.00	147.00	131.63	9.81	-.255	.427	-1.338	.833
Hip Joint right	30.00	138.00	168.00	156.83	6.04	-.998	.427	2.238	.833
Shoulder joint Right	55.00	129.00	184.00	152.73	13.65	.333	.427	-.127	.833
Elbow joint Right	25.00	160.00	185.00	169.93	6.19	.744	.427	.545	.833
Wrist Joint Right	28.00	152.00	180.00	165.10	8.22	.258	.427	-1.152	.833
Ankle Joint left	30.00	108.00	138.00	123.03	8.27	-.081	.427	-.834	.833
Knee Joint left	53.00	134.00	187.00	162.40	13.31	-.633	.427	.090	.833
Hip Joint left	30.00	99.00	129.00	113.43	8.13	.173	.427	-.797	.833
Shoulder joint left	34.00	9.00	43.00	25.90	11.19	-.177	.427	-1.355	.833
Elbow joint left	56.00	49.00	105.00	84.27	18.88	-.782	.427	-.667	.833
Wrist Joint left	58.00	119.00	177.00	150.57	18.40	-.109	.427	-1.457	.833

N=30

For testing the normality of the data (Table 1) skewness and kurtosis (descriptive statistics) has been performed. As a guideline, a skewness value more than twice its standard error indicates a departure from symmetry. Since maximum of the variables except the Hip Joint Right skewness is lesser than twice its standard error, hence maximum of the variables were symmetrically distributed. Owing to this principle the Hip Joint Right was negatively skewed as its value was more than twice its standard error. Thus, it can be interpreted that the performance of the subjects on Hip Joint Right was more on the upper side and higher than the mean value. Similarly, as a guideline, kurtosis values more than twice its standard error indicates a significant kurtosis. Since maximum of the variables except the Hip Joint Right kurtosis is lesser than twice its standard error, hence maximum of the variables have normal kurtosis. Owing to this principle the Hip Joint Right was leptokurtic as its value was positive. Thus, it can be interpreted that the performance of the subjects on Hip Joint Right was lightly spread and concentrated around the mode.

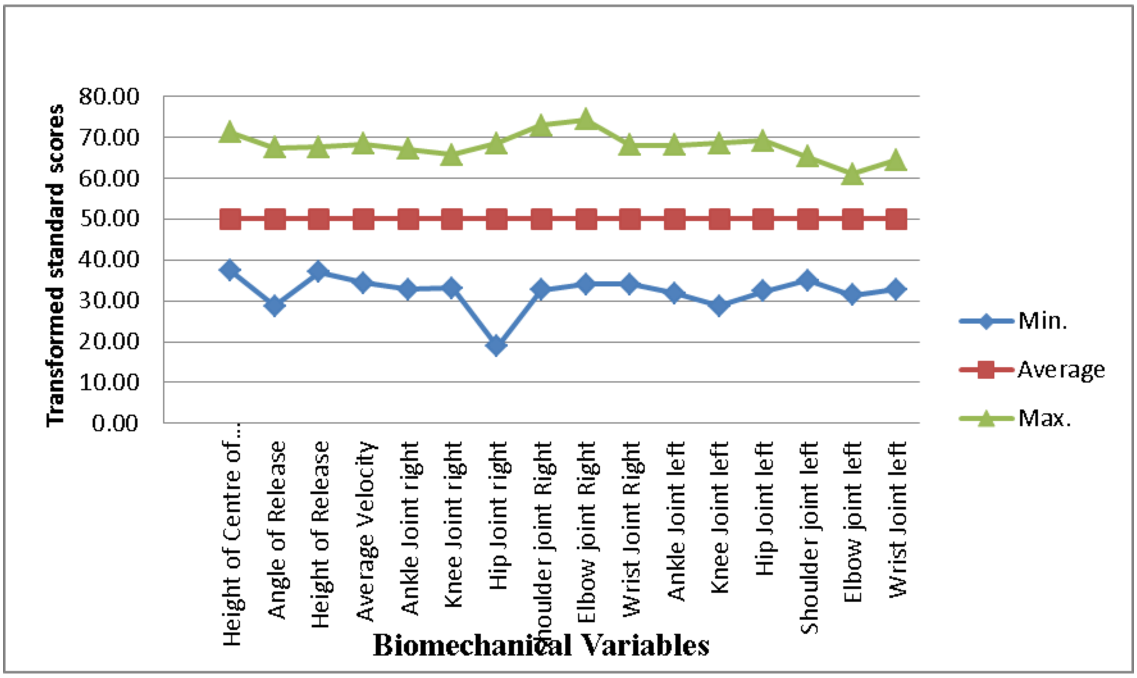

Figure 5: Graphical Representation of Profile of Identified Biomechanical variables

Here by looking at the identified biomechanical variables of leg spin bowlers in cricket. we could say that for being a leg spin bowlers in the game of cricket one must fall within the above range of biomechanical parameters (i.e. Height of Center of Gravity, Angle of Release, Height of Release, Average Velocity, Ankle Joint Right, Knee Joint Right, Hip Joint Right, Shoulder Joint Right, Elbow Joint Right, Wrist Joint Right, Ankle Joint Left, Knee Joint Left, Hip Joint Left, Shoulder Joint Left, Elbow Joint Left & Wrist Joint Left) shown in Figure 5. It helps to know the minimum and the maximum scores within which the player must fall. The profile also helps the coaches to train their players accordingly and to mould them as national players. It also helps in talent identification as per the requirement of a particular sport. It also gives an idea to the coaches so that they can work on the weak points of the players so that they can perform better and develop as complete sports persons.

Section B: Pearson's Product Moment Correlation for Evaluating the Relationship of Indentified Biomechanical Variables with Lateral Deviation of Ball

The scores of each of the identified biomechanical variables of the leg spin bowlers were correlated with lateral deviation of the ball, in order to find out the relationship, which are depicted in Table 2.

Table 2: Product Moment Correlations of Biomechanical Variables with Lateral Deviation of the Ball

Variables	Correlation Coefficient
Height of Center of Gravity	0.228
Angle of Release	0.965*
Height of Release	0.261
Average Velocity	0.541*
Ankle Joint right	0.100
Knee Joint right	-0.052
Hip Joint right	-0.207
Shoulder joint Right	-0.233
Elbow joint Right	-0.392*
Wrist Joint Right	0.074
Ankle Joint left	-0.135
Knee Joint left	0.168
Hip Joint left	0.402*
Shoulder joint left	-0.383*
Elbow joint left	0.002
Wrist Joint left	0.049

*Correlation is significant at the 0.05 level. Significant value of the correlation coefficient at 0.05 level with 28 df = 0.361.

Table 2 reveals that the significance level for each of the correlation coefficients at 0.05. Significance has been tested for two-tailed test. The correlation coefficient with mark (*) indicates that it is significant at 5% level. Angle of Release (r= 0.965), Average Velocity (r= 0.541), Elbow joint Right (r= -0.392), Hip Joint left (r= 0.402), and Shoulder joint left (r= -0.383) was significantly correlated to Lateral Deviation of Ball. Whereas no significant relationship was obtained between rests of the biomechanical variables to the performance of lateral deviation of the ball. Therefore it was evident that some biomechanical variables did not show a significant relationship to lateral deviation of the ball and were less contributing to lateral deviation of the ball as shown in above. Out of all the variables which hold a significant relationship Angle of Release, Average Velocity and Hip Joint left are positive in nature and Elbow joint Right and Shoulder joint left are negative in nature.

Section C: Multiple Linear Regressions for evaluating the contribution of Identified Biomechanical Variables and construction of Predictive Model

Multiple regression analysis was employed in order to predict the magnitude deviation of ball on the basis of identified biomechanical variables. In using the linear regression method for developing regression model, the assumptions were tested. Both dependent and independent variables were ratio data and the linear relationship exists between dependent and independent variables it was tested through scatter plot graphs and was fulfilled as all the variables were found to be linear in nature.

Table 3: Model Summary along with the Values of R and R^2

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.965[a]	.932	.929	2.46	.932	382.50	1	28	0.000
2	.972[b]	.945	.941	2.24	.014	6.73	1	27	0.015

a. Predictors: (Constant), Angle of Release

b. Predictors: (Constant), Angle of Release, Hip Joint right

c. Dependent Variable: Lateral Deviation of Ball

N=30; *Significant at 0.05 level; $F_{.05} = 4.20$

Table 3 reveals that lateral deviation of ball on the basis of biomechanical variables. Two regression models have been presented. In the second model, the value of R^2 is 0.945, which is maximum and therefore, second model shall be used to develop the regression equation. The second model has two independent variables, viz. Angle of release and Hip joint right have been identified and therefore, the regression equation was developed based on these two variables only. Since R^2 value for this model was 0.945, therefore these two independent variables explain 94.5% variations in the performance of lateral deviation of ball in leg bowling. Thus, this model is quite appropriate to develop the regression equation.

Table 4: ANOVA table showing F-values for all the Models

Model	Sum of Squares	Df	Mean Square	F	P-value

1	**Regression**	2310.56	1	2310.56	382.50*	0.000[b]
	Residual	169.14	28	6.041		
	Total	2479.69	29			
2	**Regression**	2344.32	2	1172.16	233.79*	0.000[c]
	Residual	135.37	27	5.014		
	Total	2479.69	29			

a. Dependent Variable: Lateral Deviation of Ball

b. Predictors: (Constant), Angle of Release

N=30; *Significant at 0.05 level; $F_{.05} = 4.20$

Table 4 reveals that F-values for all the models have been shown. The F-value for the second model was highly significant; it concluded that the model selected was highly efficient also.

Table 5: Regression Coefficients of Biomechanical variables to the performance on Lateral Deviation of Ball

		Unstandardized Coefficients		Standardized Coefficients			Correlations		
	Model	**B**	**Std. Error**	**Beta**	**t**	**Sig.**	**Zero-order**	**Partial**	**Part**
1	**(Constant)**	-60.77	4.539		-13.39	0.000			
	Angle of Release	8.66	.443	.965	19.56	0.000	.965	.965	.965
2	**(Constant)**	-31.59	11.980		-2.64	0.014			
	Angle of Release	8.56	.405	.954	21.13	0.000	.965	.971	.950
	Hip Joint right	-.180	.069	-.117	-2.60	0.015	-.207	-.447	-.117

a. Dependent Variable: Lateral Deviation of Ball

Table 5 reveals that the unstandardized and standardized regression coefficient in all the two models. In the second model t-values for the entire two regression coefficient were significant as there significant values (p-values) were less than 0.05. Thus, it concluded that the variables; Angle of Release and Hip Joint Right significantly explain the variations in the lateral deviation of ball.

Regression Equation: With the unstandardized regression coefficients (β) of the second model shown in Table 5, the regression equation was developed which was:

Lateral Deviation of ball = -31.59 – 8.56 × (Angle of Release) + -0.180 × (Hip Joint Right)

4. Discussion

Present study was conducted with the purpose to investigate the relationship of identified biomechanical variables with lateral deviation of ball and to identify the biomechanical variables which contributes significantly towards lateral deviation of spin bowling. For ease of discussion and clarity in understanding the findings has been discussed.

In case of selected biomechanical variables, the angular and linear biomechanical variables have exhibited significant relationship with the lateral deviation of ball in spin bowling. The average velocity of the ball is slow regime (13.96±1.04). Range of Average Velocity was 3.53. This finding is in agreement with others viz. Sayers & Lelimo, 2007; the bowling speed for the leg spin bowler, average velocity ranged from 18.2 to 21.2 m/s, putting him in the slow bowling regime. McLeod and Jenkins (1991) reported that, if a ball deviates in direction when it is less than 200 ms away from the batter, there will be insufficient time to alter a given response. Typically, wrist-spin bowlers deliver the ball at speeds between 17.9 and 26.8 ms- 1 (Abernethy, 1981). Therefore, at the slowest speed, if the bowler lands the ball less than 3.58 m in front of the batter (i.e. when the ball is less than 200 ms away). The Angle of Release was significantly correlated to Lateral Deviation of Ball (r= 0.965), positively correlated, also the Average Velocity was significantly correlated to Lateral Deviation of Ball (r= 0.541), Average velocity also positively correlated, Elbow joint Right was significantly correlated to Lateral Deviation of Ball (r= -0.392), it's negative in nature, The greater range of elbow extension recorded by the bowlers is likely to have contributed to the increased ball deviation. Hip Joint left was significantly correlated to Lateral Deviation of Ball (r= 0.402), positive in nature and Shoulder joint left was significantly correlated to Lateral Deviation of Ball (r= -0.383) its negative in nature.

At the time of the delivery, the bowler pivots his body on the toe ball of the front foot leg. This helps the bowler to rotate his rear leg hip so that the rear leg comes forward. It will help in rotation of the ball, which results in more deviation from the pitch. At the time of pivoting, the angle of hip joint increases. Hence this increase angle of the hip joint positively helps the leg spinners to deviate the ball more from the pitch. The bowling arm follows a close to normal swing pattern similar to that of sprinting until the point of back foot strike, also the initiation phase of upper arm circumduction starts at the hip joint with the elbow fully extended or at a constant angle The initiation phase of upper arm circumduction occurs between back foot and front foot strike. The period back foot impact to ball release also indicated that this is an important contributor in creating ball rotation. Currently, it is believed by coaches that the hips and shoulders should be pointing towards the target at back foot contact, and the hips and shoulders should then counter rotate following ball release (Such, 2007). Just prior to ball release, bowlers undergo quick acceleration at the wrist joint which is then transferred to the hand segment for ball release. Movements occur in different planes into wrist joint depending on the bowler; from a flexed position wrist-spin bowlers undergo extension and radial deviation (Woolmer et al., 2008). These are all critical in producing ball revolutions and play an important role in influencing the aerodynamic properties (e.g. drift in spin bowlers) and the deviation post bounce that is observed in spin bowlers (Baker, 2010; Mehta, 2005; Robinson & Robinson, 2013).

Coaches are believed that the range of hip flexion is also important. The reality of the hip action in bowling is more complex, it can be important factors. Hip flexion is not only dependent on the torques generated by the non-bowling arm, but also by arm configurations which determine the position of the centre of gravity for the whole upper body.

In leg spin bowling the regression equation was reliable as the value of R^2 was 0.945. The two variables selected in that regression equation explain 94.5% of the total variability in lateral deviation of ball was good. Since F-value for that regression model was highly significant, the model was reliable. At the same time all the regression coefficient in that model were highly significant and therefore all the two variables selected in the model viz. Angle of release and Hip joint right were valid in estimating the lateral deviation of ball of a leg spin bowling.

Foster et al., (1989) reported that an increased knee and hip angles were identified as contributing to the increased height of release. When the knee angle at ball release has been analysed in relation to bowling speed, faster bowlers have been suggested to have a more extended front knee at front foot impact and ball release (Davis and Blanksby, 1976; Burden and Bartlett, 1990; Stockill and Bartlett, 1993). Elliott et al. (1986) suggested if the ball release speeds is greater that may be attainable with a more extended front knee (>150°), as it provides a more effectual lever to deliver the ball.

There are so many factors that contribute to a successful spin bowler, imparting a high level of revolutions on the ball is seen as critical during the delivery phase and the main causation responsible for turning or spinning the ball off the pitch (Woolmer et al., 2008). Wrist movement is the main mechanics mentioned in the literature that relates the ball to spinning (Philpott, 1973; 1978; WACA, 2003). Wrist cocking; a combination of hyperextension and radial deviation, at arm horizontal, and then un-cocking (flexion) through a range of < 308, would appear to assist in developing the required side and top-spin noted in the literature (Cricket Australia, 2005).

The success of spin bowlers foremost depends on their aptitude to get perfect command over the length of the ball with different variations and control over the trajectory of the ball, for this they should practice for long period of times. Spinners must hope to trick the batsman in the air, to do so, they must bowl slow enough to set him some problem in gauging the arc of their flight, but not so slow that he can readily move out to the pitch of the ball and kill the break, or play it comfortably off the back foot. On the other hand, they try to bowl too fast; they will lose this asset and very likely their length as well.

5. Conclusions

In this study, we aimed to develop a biomechanical method of evaluating leg-spin bowling performance in cricket. This method successfully measured all the essential biomechanical variables of a spinning ball. Considering the purpose along with objectives of the study, based on the analysis and within the limitations of present investigation, conclusions derived were: The selected average values of different identified variables had contribution at the time of spin bowling (at the time of release). Result of the minimum and maximum scores was provided a boundary of identified variable scores at the time of spin bowling. The biomechanical variables namely Angle of Release, Average Velocity, Elbow joint Right, Hip Joint left and Shoulder joint left was found significantly related with the lateral deviation of ball in leg-spin bowling. Angle of Release and Hip joint right were valid in estimating the lateral deviation of ball of a leg-spin bowling. The various models developed in the present study helps the professionals for predicting the lateral deviation of the ball in leg-spin bowling. This result can be used for many purposes: 1. to objectively analyse the performance of leg-spin bowling; 2. define model previously unknown to coaches and players.

Furthermore, the model was developed to provide prompt feedback to the bowler, which is important for skill acquisition, giving bowlers the opportunity to modify their deliveries under the instruction of a qualified coach. In this dimension there is lack of critical literature and thus demands focus for future researches. Such research is essential to develop separate coaching protocols for leg-spin bowling and should be pursued in many aspects of sports biomechanics. We hope this study has identified the need to make wider the methodology used when trying to optimize any sporting performance.

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