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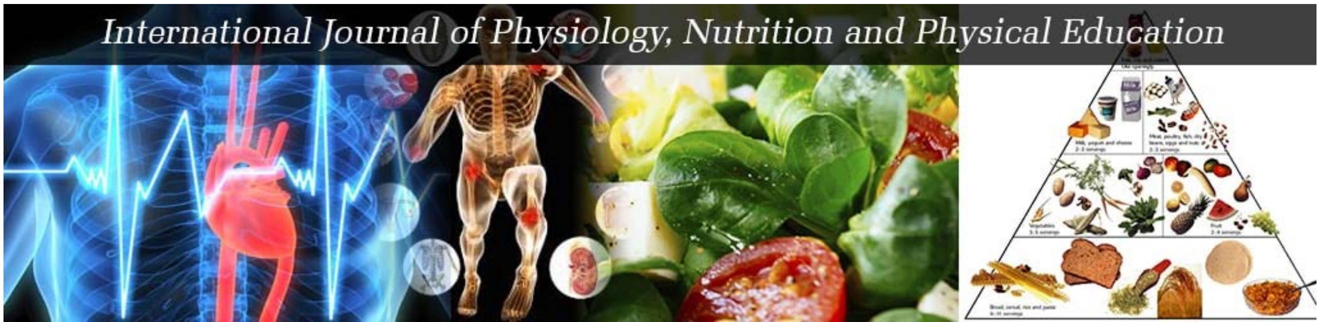

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Biomechanical analysis of selected kinematic variables in release phase of medium pace bowling in cricket with accuracy: A detailed structural equational model

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Abstract
Cricket is not just about hitting runs but for a good team performance bowling is also very important.The art of pace bowling in cricket is one of the toughest and also important skills to execute. Accuracy plays a very vital role in making a pace bowler more successful in modern day cricket, there can be many factors affecting the accuracy of a pace bowler in cricket, hence for the purpose of the study the release phase was analyzed biomechanically. A total of 30 medium pace bowlers were selected by purposive sampling method from cricket academies of Gwalior, Madhya Pradesh. To, evaluate the accuracy of the bowlers Richard Aldworth Stretch Pace Bowling Test was used, the whole process was recorded through videography technique and later the data was analyzed. For the purpose of the analysis Structural Equational Modeling was employed with the help of SPSS AMOS 23 software. in release phase it was seen that angle of right shoulder (.048), right hip (***) and left wrist (.007) accounts 49% variance in predicting the center of gravity than any other variable used in this study.
And we can also conclude that because of the significant variance shown by the variables i.e. angle of right ankle (.023), angle of right elbow (.010) and angle of left ankle (.036) accounts almost 42% variance in predicting the accuracy in release phase of pace bowling in cricket than any other variable used in this study.

Keywords: Biomechanics; Kinematic; Accuracy and Medium-pace bowlers

Introduction
Cricket is one of the most popular games which are played across the globe; the game of cricket consists of skills like batting, bowling, wicket-keeping and fielding. The art of pace bowling in cricket is one of the toughest and also important skills to execute.
The game of cricket is not just about making runs, because the runs will not matter if it can’t be defended, and the best way to defend any score is to dismiss the batsman, and that’s what the bowlers tends to do. When we use the term accuracy then one thing that comes in mind is the line and length of the bowl, or in general term we can say that a bowler has to try to always pitch the bowl in the good length area as frequent as possible. A good length ball is a ball which creates a kind of confusion or a degree of uncertainty weather to go on front foot or to play on back foot, and if you want to play a good length delivery then it has to be played straight and that to defensively.
As unlike pace bowlers they don’t just charge in with maximum of their energy, as pace is not the only factor they have to keep in mind. Accuracy and control are the main weapons that fetch the wickets and make a medium pacer successful.
Accuracy plays a very vital role which is very much attached to a medium pace bowler’s performance, if you will see the record book then you will find the names of those medium pace bowlers who were very much consistent with their accuracy and they also managed to take wickets, and if you will see the leading wicket takers of the world cricket the most successful ones are the medium pace bowlers, James Anderson, Glen McGrath, Shaun Pollock, Wasim Akram, Kapil Dev, Dale Steyn and many more.
“Having good pace always makes one unique, but one need to work on the control, the Australian quick Mitchell Johnson is a very good example of that, we all know how quick he was but in the ashes series he worked on his control and accuracy was but in the ashes series,

He worked on his control and accuracy, so from a dangerous bowler he became a lethal bowler, so always one should try to bowl quick and fast but also work on one's accuracy", said the Australian Legend Glen McGrath. (Bhose, 2018) [9]

Materials and methods

Selection of Subjects

For the purpose of the study 30 male cricket players were chosen from the cricket academies of Gwalior who were basically pace bowlers and were having high level skills in pace bowling. 15 bowlers were taken from Yuvraj Singh Center of Excellence, ITM University, Gwalior, Madhya Pradesh and the other 15 bowlers were chosen from Rishi Galav Cricket Club Gwalior, Madhya Pradesh. Therefore, it was considered that the subjects possess reasonable level of technique of pace bowling in cricket. The age range of subjects was from 18 to 25 years.

Selection of Variables

Linear kinematic variables selected for the purpose of the study at release phase are:

- Center of gravity of the body at run-up phase
- Speed of the ball

Angular kinematic variables selected for the purpose of the study at release phase are:

- Angle at right and left wrist
- Angle at right and left shoulder joint
- Angle at right and left elbow joint
- Angle at right and left hip joint
- Angle at right and left knee joint
- Angle at right and left ankle
- Position of head

Criterion Measure

Here the accuracy of medium pace bowling of each selected subject will be taken as a criterion of measurement of the present study. The total performance of the medium pace bowling will be recorded on the basis of the skill execution and later will be evaluated by Richard Aldworth Stretch Pace Bowling Test. The reliability of this test is 0.85; the validity of this test is 0.81 whereas the objectivity of this test is 0.78.

Procedure for Collection of Data

A total of 30 medium pace bowlers was chosen for the purpose of the study, so each of the bowlers bowled ten legal deliveries, each of the delivery was assigned a maximum of ten marks, hence the maximum score a bowler can score is 100. It was ensured that the bowlers must bowl as they are bowling in a match situation to get a data as reliable as possible. The standard cricket leather ball was used for the purpose of the study. The target area according to the test was also marked on the pitch. The target area was marked using measuring tape, lime powder, nails and rope. At first the area was measured and marked on a standard cricket pitch with the help of chalk and later full marking was done with the help of strings and lime powder. To facilitate the testing a scorer was assigned for the proper scoring of the bowlers on a score sheet. It's upon the bowler's feasibility that from which side of the wicket they can bowl (over the wicket or around the wicket) but over arm action was must. The researcher made sure they would bowl as if they are bowling in a match situation. Each of the bowlers delivered ten legal deliveries aiming the target area marked on the pitch and any ball pitching or striking over the line of the target area was counted as a legal delivery to the inner section (i.e. the higher point/score). All the points were scored for each of the ball striking in the market target area which is shown in table below.

Table 1: Scoring chart of Richard Aldworth Stretch Pace Bowling Test

Target Area	Slow Bowlers	Medium Bowlers
A	10	10
B	8	10
C	6	8
D	4	6
E	2	4
Outside E	0	2

The bowlers were made to bowl on alternate basis and their score was recorded accordingly after each of the legal delivery. Hence, the total score of each bowler after ten deliveries was the score of each bowler, the more the score the more accurate will be the bowler

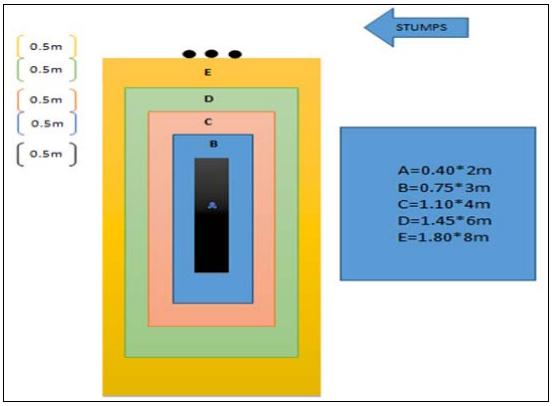

Fig 1: Bowling test records

Filming Protocol

The method of videography was employed for the biomechanical analysis of different phases of pace bowling in cricket with accuracy. GoPro Hero 5 camera was used with the frequency of 120 frames per second to capture the movement. The camera was placed on the sagittal plane from the subjects on their right hand side as all the subjects taken were right handed.

The speed of the bowler was calculated with the help of Bushnell Velocity Gun in nearest km/hr.

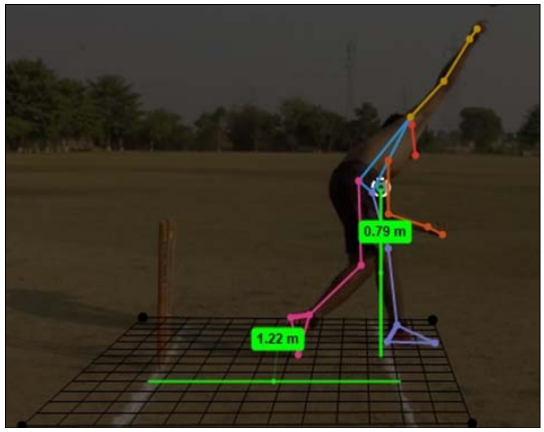

Fig 2: Centre of gravity at the moment release

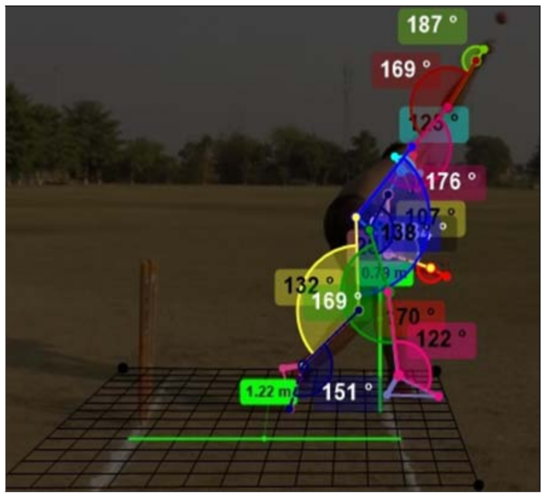

Fig 3: Angles of different joints at release phase

Statistical Procedure

The biomechanical analysis of selected kinematic variables with accuracy among different phases of pace bowling in cricket was done by Structural Equation Modeling by IBM SPSS AMOS 23 and for testing of hypothesis the level of significance was set at 0.05.

Results and discussions

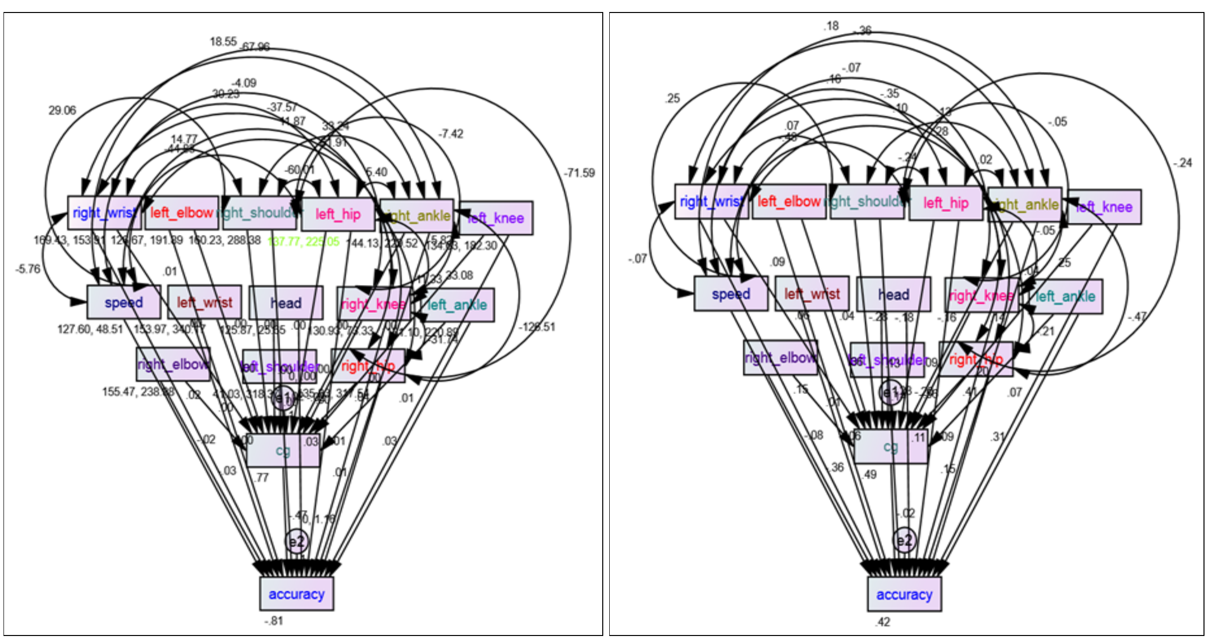

Fig 4: Structural Equation Modeling

Illustration of unstandardized and standardized values of release phase

Above figure displays the all the unstandardized values (left hand side) of release phase, here the covariances between the exogenous and endogenous variables along with the margin of error, here we can also find out the direct and indirect relationship of variables with each other and how significantly or insignificantly each of the exogenous variables are affecting the endogenous variables are exhibited in this figure.

Above figure displays all the standardized values (right hand side) of release phase, here the correlation between the exogenous and endogenous variables along with the margin of error, here we can also find out the direct and indirect relationship of variables with each other and how significantly or insignificantly each of the exogenous variables are affecting the endogenous variables is exhibited in this figure.

Estimates (release phase - Default model)
Scalar Estimates (release phase - Default model)
Maximum Likelihood Estimates

Table 2: Regression Weights: (Release Phase - Default Model)

			Estimate	S.E.	C.R.	P
CG	←	Right Wrist	.000	.001	.407	.684
CG	←	Left Elbow	.000	.001	.266	.790
CG	←	Right Shoulder	-.001	.001	-1.975	.048
CG	←	Head	.002	.002	1.012	.311
CG	←	Left Hip	-.001	.001	-1.269	.205
CG	←	Right Ankle	-.001	.001	-1.030	.303
CG	←	Left Knee	.001	.001	1.027	.305
CG	←	Right Knee	-.001	.001	-.653	.514
CG	←	Right Hip	-.002	.001	-3.604	***
CG	←	Left Shoulder	.001	.001	1.058	.290
CG	←	Right Elbow	.000	.001	.053	.957
CG	←	Left Wrist	.001	.001	2.687	.007
CG	←	Left Ankle	.001	.001	1.513	.130
Accuracy	←	Right Wrist	.017	.019	.896	.370
Accuracy	←	Left Elbow	.009	.014	.602	.547
Accuracy	←	Head	.030	.040	.756	.450
Accuracy	←	Right Shoulder	-.019	.014	-1.361	.174
Accuracy	←	Left Hip	-.018	.016	-1.156	.248
Accuracy	←	Right Ankle	.038	.017	2.277	.023
Accuracy	←	Left Knee	.007	.015	.455	.649
Accuracy	←	Speed	-.017	.035	-.478	.633
Accuracy	←	CG	-.473	3.838	-.123	.902
Accuracy	←	Left Wrist	.004	.012	.349	.727
Accuracy	←	Right Elbow	-.033	.013	-2.570	.010
Accuracy	←	Right Hip	.012	.016	.723	.470
Accuracy	←	Left Ankle	.029	.014	2.092	.036
Accuracy	←	Right Knee	.015	.026	.580	.562

*** denotes the values are significant at 0.01 level

In Table no 2 we can see the direct impact of the independent variables over the dependant variables, the values which are marked in *** are significant at 0.01 level and the P- values which are less than 0.05 are having a significant relation in contribution towards their dependant counterpart. Here we can see that when a bowler bowls a delivery, and when he is in his release phase the center of gravity is positively affected by the angle of right shoulder (.048), right hip (***) and left wrist (.007).

When it came to accuracy in the time of release phase the variable like the angle of right ankle (.023), angle of right elbow (.010) and angle of left ankle (.036) showed the significant contribution towards increasing the accuracy in medium- pace bowling.

Table 3: Standardized Regression Weights: (Release Phase - Default Model)

			Estimate
CG	←	Right Wrist	.063
CG	←	Left Elbow	.035
CG	←	Right Shoulder	-.283
CG	←	Head	.134
CG	←	Left Hip	-.177
CG	←	Right Ankle	-.163
CG	←	Left Knee	.136
CG	←	Right Knee	-.094
CG	←	Right Hip	-.560
CG	←	Left Shoulder	.140
CG	←	Right Elbow	.007
CG	←	Left Wrist	.355
CG	←	Left Ankle	.200
Accuracy	←	Right Wrist	.148
Accuracy	←	Left Elbow	.085
Accuracy	←	Head	.109
Accuracy	←	Right Shoulder	-.226
Accuracy	←	Left Hip	-.195
Accuracy	←	Right Ankle	.411
Accuracy	←	Left Knee	.066
Accuracy	←	Speed	-.081
Accuracy	←	CG	-.024
Accuracy	←	Left Wrist	.055
Accuracy	←	Right Elbow	-.364
Accuracy	←	Right Hip	.148
Accuracy	←	Left Ankle	.307
Accuracy	←	Right Knee	.090

Table no 3 exhibits the standardized values of the previous table i.e. Table no 2, so, for further use and study the standardized estimates can be used.

Table 4: Means: (release phase - Default model)

	Estimate	S.E.	C.R.	P
Left Elbow	126.667	2.572	49.242	***
Right Shoulder	160.233	3.153	50.812	***
Right Wrist	169.433	2.304	73.546	***
Left Hip	137.767	2.786	49.455	***
Right Ankle	144.133	2.813	51.234	***
Left Ankle	131.100	2.760	47.502	***
Right Knee	130.933	1.590	82.340	***
Right Hip	135.833	3.309	41.049	***
Left Wrist	153.967	3.425	44.955	***
Right Elbow	155.467	2.871	54.157	***
Left Shoulder	41.033	3.313	12.384	***
Left Knee	134.633	2.507	53.698	***
Head	125.867	.940	133.837	***
Speed	127.600	1.293	98.662	***

*** denotes the values are significant at 0.01 level

In Table no 4 we can see the mean estimate of all the independent variables used in this study to depict the accuracy, as from the table we can clearly quote that all the estimates of mean of independent variables used in this study shows significant relationship at 0.01 level of significance.

Table 5: Intercepts: (Release Phase - Default Model)

	Estimate	S.E.	C.R.	P
CG	.775	.444	1.743	.081
Accuracy	-.807	10.661	-.076	.940

*** denotes the values are significant at 0.01 level

Here in Table no 5 both the independent variables are shown with their intercept estimates, the center of gravity didn't shows any significant relationship at 0.05 level of significance, whereas accuracy shows insignificant relationship at 0.05 level of significance.

Table 6: Covariance's: (Release Phase - Default Model)

			Estimate	S.E.	C.R.	P
Right Wrist	↔	Right Shoulder	14.766	39.218	.377	.707
Right Shoulder	↔	Left Hip	-60.012	48.601	-1.235	.217
Right Shoulder	↔	Right Ankle	33.236	48.171	.690	.490
Right Shoulder	↔	Right Knee	-7.418	27.039	-.274	.784
Right Shoulder	↔	Right Hip	-71.594	57.744	-1.240	.215
Right Wrist	↔	Left Hip	30.234	35.013	.864	.388
Right Wrist	↔	Right Knee	-37.571	20.925	-1.796	.073
Right Wrist	↔	Right Hip	61.906	42.631	1.452	.146
Left Hip	↔	Right Ankle	5.398	42.215	.128	.898
Left Hip	↔	Right Knee	-5.816	23.879	-.244	.808
Left Hip	↔	Right Hip	11.328	49.685	.228	.820
Right Ankle	↔	Right Knee	33.076	24.861	1.330	.183
Right Ankle	↔	Right Hip	-126.511	55.362	-2.285	.022
Right Hip	↔	Right Knee	-31.744	28.943	-1.097	.273
Right Wrist	↔	Right Ankle	-67.958	37.113	-1.831	.067
Speed	↔	Right Shoulder	29.060	22.616	1.285	.199
Speed	↔	Right Wrist	-5.760	16.081	-.358	.720
Speed	↔	Left Hip	-44.827	21.112	-2.123	.034
Speed	↔	Right Ankle	18.553	19.894	.933	.351
Speed	↔	Right Knee	-4.093	11.101	-.369	.712
Speed	↔	Right Hip	11.867	23.151	.513	.608

In the above Table No 6, we can see the inter-relationship between the variables, the double arrow between the variables shows the covariance between the indicator variables and the independent variables. Here we can see that how much the variables are inter-dependant on each other. As we can see from the table that the covariance between right ankle and right hip is showing significant relationship (.022) and also the covariance between speed and left hip shows significant relationship (.034) at 0.05 level of significance in the release phase of the pace bowling in cricket.

Table 7: Variances: (Release Phase - Default Model)

	Estimate	S.E.	C.R.	P
Right Wrist	153.912	40.419	3.808	***
Left Elbow	191.889	50.392	3.808	***
Head	25.649	6.736	3.808	***
Right Shoulder	288.379	75.732	3.808	***
Left Hip	225.046	59.100	3.808	***
Right Ankle	229.516	60.274	3.808	***
Left Knee	182.299	47.874	3.808	***
Left Wrist	340.166	89.332	3.808	***
Right Elbow	238.982	62.760	3.808	***
Right Hip	317.539	83.390	3.808	***
Left Ankle	220.890	58.009	3.808	***
Right Knee	73.329	19.257	3.808	***
Left Shoulder	318.366	83.607	3.808	***
e1	.003	.001	3.808	***
Speed	48.507	12.738	3.808	***
e2	1.158	.304	3.808	***

*** denotes the values are significant at 0.01 level

In Table no 7 we can get the variances showed by each of the independent variables in the whole of data set. In this table along with the independent variables we can also see the variance of error that we included in the study as e1 and e2. As from the above table we can clearly conclude that all the independent variables taken for the purpose of the study shows significant variance in release phase of pace bowling in cricket.

Table 8: Squared Multiple Correlations: (Release Phase - Default Model)

	Estimate
CG	.493
Accuracy	.419

The Table no 8 displays us about the squared multiple correlation in the release phase of pace bowling in cricket. The squared multiple correlations represent the proportion of variance in the dependant variable that is explained or shown by the set of independent variables or predictors.

So, here from this table above the researcher can conclude that the because of the significant variances shown by the variables i.e. angle of right shoulder (.048), right hip (***) and left wrist (.007). Accounts 49% variance in predicting the center of gravity than any other variable used in this study. And we can also conclude that because of the significant variance shown by the variables i.e. angle of right ankle (.023), angle of right elbow (.010) and angle of left ankle (.036) accounts almost 42% variance in predicting the accuracy in release phase of pace bowling in cricket than any other variable used in this study.

Table 9: Standardized Total Effects (Release Phase - Default Model)

Variables	CG	Accuracy
Left Shoulder	.140	-.003
Right Knee	-.094	.093
Left Ankle	.200	.302
Right Ankle	-.560	.162
Right Elbow	.007	-.364
Left Wrist	.355	.047
Left Knee	.136	.062
Right Ankle	.163	.415
Left Hip	-.177	-.191
Right Shoulder	-.283	-.219
Head	.134	.106
Left Elbow	.035	.084
Right Wrist	.063	.147
CG	000	.024
Speed	.000	.081

Table no 9 exhibits the standardized total effect of the independent variables over the dependent variables in release phase of pace bowling in cricket.

Table 10: Standardized Direct Effects (Release Phase - Default Model)

Variables	CG	Accuracy
Left Shoulder	.140	.000
Right Knee	-.094	.090
Left Ankle	.200	.307
Right Ankle	-.560	.148
Right Elbow	.007	-.364
Left Wrist	.355	.055
Left Knee	.136	.066
Right Ankle	-.163	.411
Left Hip	-.177	-.195
Right Shoulder	-.283	-.226
Head	.134	.109
Left Elbow	.035	.085
Right Wrist	.063	.148
CG	000	-.024
Speed	.000	-.081

Table no 10 displays the standardized direct effect of the independent variables over the independent variables in release phase of pace bowling in cricket.

Table 11: Standardized Indirect Effects (Release Phase - Default Model)

Variables	CG	Accuracy
Left Shoulder	.000	-.003
Right Knee	.000	.002
Left Ankle	.000	-.005
Right Ankle	.000	.013
Right Elbow	.000	.000
Left Wrist	.000	-.009
Left Knee	.000	-.003
Right Ankle	.000	.004
Left Hip	.000	.004
Right Shoulder	.000	.007
Head	.000	-.003
Left Elbow	.000	-.001
Right Wrist	.000	-.002
CG	000	.000
Speed	.000	000

Table no 11 displays the standardized indirect effect of the independent variables over the independent variables in release phase of pace bowling in cricket.

Notes for Model (Default model)

Table 12: Computation of Degrees Of Freedom (Default Model)

S. No	Parameters	Total
1	Number of distinct sample moments	152
2	Number of distinct parameters to be estimated	80
3	Degrees of freedom (152-80)	72

From Table no 12 we can get the total distinct sample along with the number of parameters that are to be estimated in the model, the difference of number of distinct sample moments and total number of parameters to be estimated will give us the degree of freedom of the model.

With this we can get to know about the type of model the researcher has prepared for the purpose of estimation, here in this case our model is over identified model as the degree of freedom is on the positive side.

Table 13: Result (Default Model)

S. No	Measures	Results
1	Chi-Square	90.995
2	Degree of Freedom	72
3	Probability Level	.036

Minimum was achieved

In Table no 13 we can see the values of chi-square and the calculated degree of freedom, as the probability level is.036, which is less than 0.05, then we can say that our model is an absolute model fit.

Model Fit Summary

Table 14: CMIN

Model	NPAR	CMIN	DF	P	CMIN/DF
Default model	80	90.995	72	.036	1.264
Saturated model	152	.000	0		
Independence model	32	154.647	120	.018	1.289

In table no 14 the CMIN value is seen, as in the table we can see that the calculated CMIN value is insignificant i.e. CMIN value (90.995) >0.05, hence we can conclude that the model is having a good fit.

Table 15: Baseline Comparisons

Model	NFI Delta1	RFI rho1	IFI Delta2	TLI rho2	CFI
Default model	.412	.019	.770	.086	.452
Saturated model	1.000		1.000		1.000
Independence model	.000	.000	.000	.000	.000

In table no 15 we will see the values of values of NFI, RFI, IFI, TLI and CFI, here the more the values are closer to 1 more the model will become a good fit model, as out of all the value of IFI is.770 which depicts the model as good fit.

Table 16: Parsimony-Adjusted Measures

Model	PRATIO	PNFI	PCFI
Default model	.600	.247	.271
Saturated model	.000	.000	.000
Independence model	1.000	.000	.000

Table no 16 gives us the Parsimony value of the model, here the Parsimony value is.600, and it shows the minimum discrepancy (chi square/degree of freedom). So, from the acquired value one can conclude that the model is a good fit according to the Parsimony PRATIO as the value is less than 5.

Table 17: RMSEA

Model	RMSEA	LO 90	HI 90	PCLOSE
Default model	.025	.000	.051	.142
Independence model	.100	.044	.143	.065

Table no 17 gives us the RMSEA value, as we can see in the table that the RMSEA value i.e. 0.025 <0.05, so we can say that the model is a good fit.

Hence, from the above model fit summary it can be concluded that the model developed for the purpose of the study is a good fit model.

Results

The results in the release phase after analyzing it biomechanically shows that the angle of right shoulder (.048), angle of right hip (***) and angle of left wrist (.007) contributes to the centre of gravity of the body significantly in release phase of the bowling, so it can be concluded that the angles of right hip, right shoulder and left wrist is positively contributing to centre of gravity in the release phase of the pace bowling, the unstandardized estimates in the release phase of bowling can conclude that with the increase of 1 unit of angles at right shoulder (-.001), right hip (-.002) and left wrist (.001) the centre of gravity decreases by -.001 units for angle of right shoulder and -.002 units for angle of right hip but it increases.001 units for angle of left wrist, the standardized estimates in this phase reveals that with the increase of 1 unit of standard deviations in the angles of right shoulder (-.283), right hip (-.560) and angle of left wrist (.355) there will be a decrease in the centre of gravity by -.283 and -.560 standard deviations but for angle of left wrist there will be a increase of.355 standard deviation in centre of gravity, this is because of the power generated from the right shoulder and right hip at the time of ball release, whereas the contribution of non-bowling arm also plays a significant role i.e. the left wrist because the bowling arm i.e. the right arm fir right handed bowlers should always be pulled near to the trunk of the body, so that the opposite anti-clockwise torque remains in the non-bowling arm.

The findings also showed that the kinematic variables i.e. angle at right ankle (.023), angle at right elbow (.010) and the angle of left ankle (.036) are having positive significant relationship over the accuracy of a bowler in release phase, so it can be concluded that the angle of right elbow, right ankle and left ankle is positively contributing to the accuracy of a bowler in release phase, the unstandardized estimates concludes that with the increase a unit in the angles of right ankle (.388), right elbow (-.033) and left ankle (.029) there will be a increase in the accuracy by.388 units because of angle of right ankle and.029 units because of angle of left ankle but in the case of angle of right elbow the accuracy decreased by -.033 units, whereas the standardized estimates revealed that when the angle of right ankle (.411), angle of right elbow (-.364) and angle of left ankle (.307) increases by 1 standard deviation then the accuracy in the time of release phase of pace bowling goes up by.411 and.307 standard deviations because of angle of right ankle and angle of left ankle respectively, but the accuracy goes down by.-364 standard deviations because of angle of right elbow, and this may be because the related studies showed that the fast bowlers should have firm and quick arm movement of the bowling arm, as it will decide the direction of line and length of the ball along with the help of two ankles of both the legs. While releasing the ball there has to be a forceful rotation of the upper limb along with a thrust as the whole body comes in a hyper-extended position and the whole movement starts from the both the ankles.

For the release phase of pace bowling, the maximum total effects are shown by angle of left wrist (.355) which has a medium effect over the centre of gravity and angle of right ankle (.415) also has a medium direct effect over accuracy, the direct effect in the findings concludes that the angle of left wrist (.355) has a medium effect over the centre of gravity directly whereas the angle of right ankle (.411) has a medium direct effect over the accuracy, the findings of indirect effects concludes that none of the independent variables has any kind of indirect effect over the centre of gravity, but angle of right ankle (.013) has a small indirect effect over the accuracy of a pace bowling in the release phase.

Conclusion

Whereas in release phase it was seen that angle of right shoulder (.048), right hip (***) and left wrist (.007) accounts 49% variance in predicting the center of gravity than any other variable used in this study.

And we can also conclude that because of the significant variance shown by the variables i.e. angle of right ankle (.023), angle of right elbow (.010) and angle of left ankle (.036) accounts almost 42% variance in predicting the accuracy in release phase of pace bowling in cricket than any other variable used in this study.

References

1. Gupta AK. Research Methodology in Physical Education. Ashok Vihar, New Delhi, India: Sports Publications, 2003.
2. Abderrehmane Rahmani, Georges Dalleau, Fabrice Viale, Christophe A. Hautier and Jeanrene Lacour, "Validity and Realiability of a Kinematic Device for Measuring the Force Developed during Squatting", Journal of Applied Biomechanics. 2000; 16:26-35.
3. Agarwal JC, Educational research (New Delhi, Ariya book depot, 1975, 109.
4. Agarwal L. Modern Eduactional Research. New Delhi, India: Dominant Publishers and distributers, 2005.
5. Agarwa, L. Modern Educational Research. New Delhi, India: Dominant Publisher and Distributors, 2006.
6. Olivier B, AV. Cricket pace bowling: the trade-off between optimising knee angle for performance advantages v. injuries prevention. SAJSM, 2015, 76-81.
7. Elliot BC, DA. Biomechanical and physical factors affecting fast bowling. Australian journal od science and medicine in sports, 1986, 16-21.
8. Barlett AB. A kinematic comparasion between elite fast bowles and college fast medium bowlers. sports biomechanics section of british association of sports sciences. leeds: BASS, 1990.
9. Bhose B. Cricket Next. Retrieved from, 2018. news18.com:https://www.news18.com/cricketnext/news/perfect-mix-of-pace-and-accuracy-makes-a-fast-bowler-lethal-glenn-mcgrath-1835843.html
10. Colin N. Introduction to research and research methods. Bradford, London: University of Bradford, 2007.
11. Con Milan, Stanislav Peharec, Petar Bacic, The major kinematic parameters of the sprint start and block acceleration, September-6-2006 Elliott B C and DJW Davis Dip RG, "Disc degeneration and the young fast bowler in cricket", Research in Sports Medicine. 2002; 3:67-74.
12. Gordon DE. Robertson GE. Research Methods in Biomechanics. New York, The United States of America: Human Kinetics, 2004.
13. D Foster BE. A biomechanical analysis of front front-on and side-on fast bowling techniques. Journal of human movements studies, 1984, 83-94.