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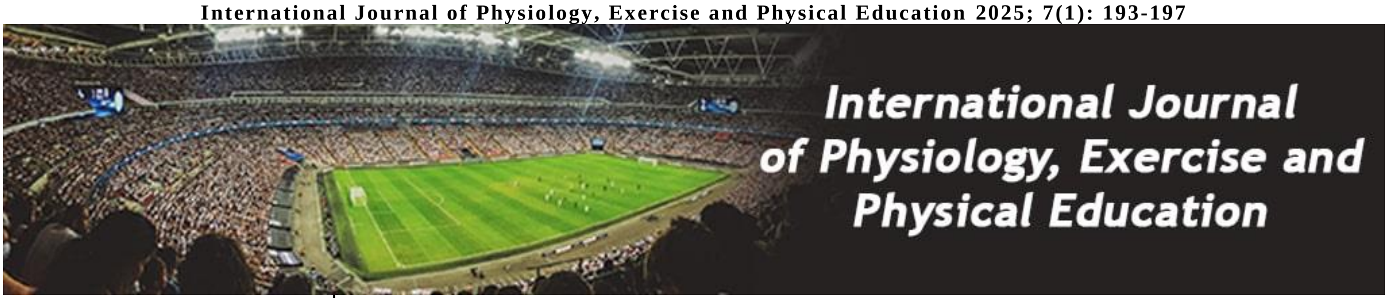

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Correlation between selected kinematic variables and performance outcomes in the javelin throw power position

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Abstract
The javelin throw is a difficult sport that calls for a great deal of coordination between numerous body parts. In this research 20 Male senior national level player aged 20-28 years had to be chosen for the study. To obtain a reliable measurement, standard and calibrated equipment like a camera, Tripod, Cones, measuring tape, etc. were used, and the study was directed under controlled conditions. The point at which the javelin is released, known as the power position, largely dictates the distance thrown. For the power position method in javelin throwing, this work develops a prediction model based on a selected kinematic characteristic. The kinematic analysis of professional javelin throwers is used to investigate the connection between the optimal power position and the kinametic variable in order to develop a prediction model. To improve throwing performance, the model aims to provide useful information on technique optimization.

Keywords: Javelin throw, power position, biomechanical variables, joint-point method, performance analysis

Introduction
The javelin throw is a highly technical and dynamic athletic event that demands a precise combination of speed, strength, coordination, and technique. One of the most critical phases in the javelin throw is the power position—the moment when the athlete transitions from the approach phase to the release, channeling maximum kinetic energy into the javelin. The effectiveness of this position plays a pivotal role in determining the overall distance of the throw.

To optimize performance, biomechanical analysis serves as an essential tool for understanding the movement patterns and forces involved in each phase of the throw. In particular, kinematic variables—such as release velocity, release angle, elbow angle, and trunk rotation—provide quantifiable insights into how the body moves during the power position and how those movements affect the throw's outcome.

This study aims to analyze the biomechanics of the power position in javelin throwing by focusing on a selected kinematic variable. By examining the relationship between this variable and throwing performance, the research seeks to develop insights that can help athletes improve their technique and achieve greater throw distances.

Methodology
Selection of Subjects
20 senior national level players from India in the 20-28 age range will be chosen as research participants for the purpose of the investigation. All of the subjects were informed of the study's goal, and they were encouraged to give each trial their all. Prior to taking part in the testing procedures, each subject gave their consent.

Selection of Variables
Based on literary evidence, correspondence with the expert and scholar's own understanding and keeping feasibility criterion in mind, the selected variables were as follows:

Dependent Variables
1. Javelin Throw Technique.
2. Power Position Technique.

Independent Variables
Kinematics variables.

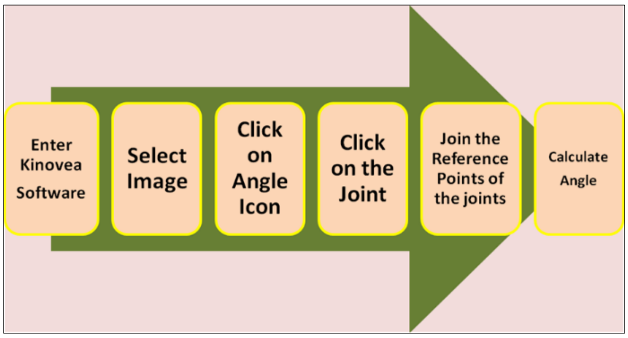
Linear kinematics
1. C.G at the execution.
2. Velocity after execution.

Angular kinematics
- Ankle joint
- Knee joint
- Hip joint
- Shoulder joint
- Elbow joint
- Wrist joint

Technique analysis procedure: Technique of the subjects in Javelin throw (Power position) collected on the basis of the subjective evaluation. The best of 03 times throwing performance on the selected trial were obtained and best techniques of throwing are used for data collection

High-speed cameras
(Frequency 240 frames) will capture the power position phase and help measure the kinematic variable accurately. Moment execution of Javelin throw (power position) will be selected for the analysis. The scholar created stick figures using sequence photos from the videography, and from those stick figures, he or she estimated specific biomechanical variables. Kinovea software created the stick figures. The technique will be performed to the subjects 3 times, with the best trail being chosen for analysis. Kinovea software will identify each subject's center of gravity during the javelin throw. Following the javelin's flight path after release will allow the velocity to be determined.

Procedure for Measuring Angular Kinematics
Measured with the aid of Kinovea software, the specified kinematic variables, such as angles at ankle joint, knee joint, hip joint, shoulder joint, elbow joint and wrist joint were selected.



Flow chart of Procedure for Measuring Selected Angular Kinematics

Viedo Protocol: This video tool enables detailed observation of specific actions within a video by allowing frame-by-frame playback in slow motion. Kinovea supports a wide range of video file formats natively, making it highly accessible. The software offers a variety of powerful features, including motion analysis, measurement tools, side-by-side comparison, and in-depth visual observations, making it a valuable asset for biomechanical and sports performance studies.

Fig 1: The subject at moment of Power position

Statistical procedure
To determine the prediction of the power position technique in javelin throw based on kinematic variables, multiple regression analysis, t-values, and partial correlation techniques were employed. For hypothesis testing, the significance level was established at 0.05.

Table 1: Correlations Matrix of Linear and Angular Kinematic Variables at Moment power position in javelin throw

Variables	Center of Gravity	Angle of Right Ankle	Angle of Left Ankle	Angle of Right Knee	Angle of Left Knee	Angle of Right Hip Joint	Angle of Left Hip Joint	Angle of Right Shoulder	Angle of Left Shoulder	Angle of Right Elbow		Angle of Left Elbow	Angle of Right Wrist	Angle of Left Wrist	Javelin Performance
Center of Gravity	Pearson Correlation	1	.160	.118	.190	.354	.081	.113	-.098	-.126	.444*	-.477*	-.053	-.042	.273
	Sig. (2-tailed)		.501	.620	.422	.125	.735	.636	.682	.598	.050	.033	.824	.859	.245
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Right Ankle	Pearson Correlation	.160	1	.285	.062	.252	.428	.441	-.298	-.042	.630**	-.157	.233	-.075	.297
	Sig. (2-tailed)	.501		.223	.794	.284	.059	.052	.202	.862	.003	.509	.322	.752	.203
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Left Ankle	Pearson Correlation	.118	.285	1	-.028	.026	-.065	.414	-.154	.201	.480*	.090	-.036	-.051	.070
	Sig. (2-tailed)	.620	.223		.906	.913	.786	.070	.516	.395	.032	.706	.880	.830	.769
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Right Knee	Pearson Correlation	.190	.062	-.028	1	.188	-.020	-.392	.280	-.642**	-.181	-.061	.174	-.372	-.091
	Sig. (2-tailed)	.422	.794	.906		.428	.932	.087	.232	.002	.444	.799	.463	.106	.703
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Left Knee	Pearson Correlation	.354	.252	.026	.188	1	.591**	.126	-.730**	-.359	.297	-.452*	-.024	-.312	.864**
	Sig. (2-tailed)	.125	.284	.913	.428		.006	.597	.000	.120	.204	.045	.922	.180	.000
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Right Hip Joint	Pearson Correlation	.081	.428	-.065	-.020	.591**	1	-.147	-.554*	-.138	.081	-.396	-.106	-.055	.748**
	Sig. (2-tailed)	.735	.059	.786	.932	.006		.538	.011	.561	.736	.084	.658	.816	.000
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Left Hip Joint	Pearson Correlation	.113	.441	.414	-.392	.126	-.147	1	-.435	.415	.721**	-.025	-.015	.056	.130
	Sig. (2-tailed)	.636	.052	.070	.087	.597	.538		.055	.069	.000	.916	.951	.816	.586
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Right Shoulder	Pearson Correlation	-.098	-.298	-.154	.280	-.730**	-.554*	-.435	1	.054	-.321	.445*	.254	.310	-.813**
	Sig. (2-tailed)	.682	.202	.516	.232	.000	.011	.055		.820	.168	.049	.280	.184	.000
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Left Shoulder	Pearson Correlation	-.126	-.042	.201	-.642**	-.359	-.138	.415	.054	1	.308	.243	.159	.540*	-.083
	Sig. (2-tailed)	.598	.862	.395	.002	.120	.561	.069	.820		.186	.303	.502	.014	.728
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Right Elbow	Pearson Correlation	.444*	.630**	.480*	-.181	.297	.081	.721**	-.321	.308	1	-.015	.204	.083	.298
	Sig. (2-tailed)	.050	.003	.032	.444	.204	.736	.000	.168	.186		.949	.388	.727	.202
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Left Elbow	Pearson Correlation	-.477*	-.157	.090	-.061	-.452*	-.396	-.025	.445*	.243	-.015	1	.108	.138	-.435
	Sig. (2-tailed)	.033	.509	.706	.799	.045	.084	.916	.049	.303	.949		.651	.563	.055
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Right Wrist	Pearson Correlation	-.053	.233	-.036	.174	-.024	-.106	-.015	.254	.159	.204	.108	1	.139	-.004
	Sig. (2-tailed)	.824	.322	.880	.463	.922	.658	.951	.280	.502	.388	.651		.559	.988
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Angle of Left Wrist	Pearson Correlation	-.042	-.075	-.051	-.372	-.312	-.055	.056	.310	.540*	.083	.138	.139	1	-.061
	Sig. (2-tailed)	.859	.752	.830	.106	.180	.816	.816	.184	.014	.727	.563	.559		.798
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Javelin Performance	Pearson Correlation	.273	.297	.070	-.091	.864**	.748**	.130	-.813**	-.083	.298	-.435	-.004	-.061	1
	Sig. (2-tailed)	.245	.203	.769	.703	.000	.000	.586	.000	.728	.202	.055	.988	.798	
	N	20	20	20	20	20	20	20	20	20	20	20	20	20	20

*. Correlation is significant at the 0.05 level (2-tailed). Significant value of r at .05 level with 18 df (2-tailed) = 0.444

**. Correlation is significant at the 0.01 level (2-tailed). Significant value of r at .01 level with 18 df (2-tailed) = 0.561

Table 2 shows the correlation between the Linear Kinematic, Angular Kinematic Variables with Javelin Power Position technique along with their significance value (p-value). The significance of these correlations has been tested for a two-tailed test. The correlation coefficient with one asterisk mark (*) indicates its significance at a 5% level. The asterisk mark (*) is put on the correlation coefficient if its value is more than the required value of the correlation coefficient for its significance at 5% level which is 0.444. For a two-tailed test, the required value of "r" for significance with 18 (N - 2) df can be seen from the critical value of the correlation coefficient.

Similarly, for the two-tailed test, the significance value for the correlation coefficient at 0.01 levels with 18 (N-2) df can be seen as 0.561. Thus, all those correlation coefficients having values more than 0.561 are significant at a 1% level. Such correlation coefficients have been seen shown with two asterisk marks (**). From Table 2, it can be seen that javelin power position technique is significantly correlated with, angle at left knee, angle at right hip, angle at right shoulder, angle at right elbow and none of javelin power position technique variables shows significant at 0.05 levels.

Table 2: Variable Regression Coefficients, t-values, and Partial Correlations of Javelin Power Position Technique

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-8.814	5.546		-1.589	.129
	Angle of Left Knee	.241	.033	.864	7.284	.000
2	(Constant)	-12.810	4.823		-2.656	.017
	Angle of Left Knee	.181	.034	.649	5.280	.000
	Angle of Right Hip Joint	.103	.035	.365	2.969	.009
3	(Constant)	-16.975	4.538		-3.741	.002
	Angle of Left Knee	.208	.032	.748	6.526	.000
	Angle of Right Hip Joint	.096	.031	.338	3.131	.006
	Angle of Left Shoulder	.013	.005	.233	2.493	.024

a. Dependent Variable: Javelin Performance

In the third model, all three regression coefficients' t-values are significant because their p-values are less than 0.05. Thus, it might be concluded that the variables Angle at Left Knee, Angle at Right Hip Joint, Angle at Left Shoulder comprehensively describe the differences in the Javelin Power Position Technique of throwing in athletics.

Regression Equation: The prediction model can be generated using the unstandardized regression coefficient (B) of the 3rd model provided in table 5:

Javelin Power Position Technique of throwing in Athletics = -16.975 + 0.208 x (Angle at Left Knee) + 0.96 x (Angle at Right Hip) - 0.13 x (Angle at Left Shoulder)

As a result, the above prediction model is reliable, as R^2 equals .880. Alternatively, 88% percent of the entire variability of the Power Position of Javelin throw is explained in the three variables used in this regression equation. This predictive model's F-value is extremely significant, implying that the model is trustworthy. The three variables used in the model name, Angle at Left Knee, Angle at Right Hip Joint & Angle at Left Shoulder, are all strongly predictive in the estimate of the current Javelin Power Position Technique of throwing in athletics.

Conclusion

Based on the understanding after discussion with the experts and supervisor, the following conclusions were drawn:

1. The linear and angular kinematic variables i.e., Angle at Left Knee, Angle at Right Hip Joint, Angle at Left Shoulder would help to javelin power position technique for chosen javelin Athletes.
2. The linear and angular kinematic variables i.e., Angle at Left Knee should be blocked (Straight) in javelin power position technique selected javelin athletes.
3. The linear and angular kinematic variables i.e. Angle at Right Hip Joint, when the right hip joint moves in the forward direction it helps in apply the maximum force upon javelin.
4. The linear and angular kinematics variables i.e. javelin power position time Angle at Left Shoulder down so that we can maximum reach the javelin.
5. Kinematics variables should be used to develop the javelin power position technique of javelin players and allows players to progress towards an excellent performance of javelin power position.
6. The model of the javelin power position technique provided a structure for analysis to enhance the javelin performance.

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