



## Regression Modeling of Linear and Angular Kinematical Variables in Javelin Throw Power Position for Performance Prediction

<sup>1</sup>Deepak Kumar and <sup>2</sup>Dr. Vijay Prakash

<sup>1</sup>Research Scholar, IIMT University, Meerut, Uttar Pradesh, India

<sup>2</sup>Assistant Professor, Department of Physical Education, IIMT University, Meerut, Uttar Pradesh, India

DOI: <https://doi.org/10.5281/zenodo.18628132>

Corresponding Author: Deepak Kumar

### Abstract

This study investigates regression modeling of linear and angular kinematical variables during the javelin throw power position to predict performance among 20 senior national-level Indian athletes aged 20-28. High-speed videography (240 fps) and Kinovea software facilitated measurement of variables like center-of-gravity velocity, joint angles (ankle, knee, hip, shoulder, elbow, wrist), and throw distance from the best of three trials. Multiple regression analysis identified the right shoulder angle as a significant predictor ( $R^2 = 0.661$ ,  $F = 35.056$ ,  $p < 0.001$ ), explaining 66.1% of performance variance. The equation-Performance =  $49.348 - 0.206 \times (\text{Right Shoulder Angle})$ -demonstrates that minimized shoulder angles enhance torque generation and energy transfer. These findings align with kinematic studies emphasizing shoulder positioning's role in kinetic chain efficiency. The model offers coaches practical guidance for power position technique optimization, with future research recommended for multivariate integration of linear-angular interactions to improve predictive accuracy in elite javelin training.

**Keywords:** Javelin Throw, Power Position, Kinematic Variables, Regression Modeling, Shoulder Angle, Performance Prediction, Sports Biomechanics

### Introduction

The javelin throws stand as one of the most technically demanding events in track and field athletics, where optimal performance hinges on the precise execution of biomechanical movements during critical phases such as the power position (Bartlett, 2007) [1]. In this phase, athletes transition from the approach run to the delivery, generating maximal force through a complex interplay of linear kinematical variables-like center of gravity velocity and stride length and angular variables, including joint angles at the knee, hip, and shoulder (Ae *et al.*, 2006) [2]. Regression modeling emerges as a powerful statistical tool to quantify these relationships, enabling accurate prediction of throw distance and identification of performance-limiting factors (Ismail *et al.*, 2016) [3].

Traditional kinematic analyses of javelin throwing have illuminated key determinants of success, such as release speed, angle of release, and spear orientation, which collectively account for up to 90% of variance in distance achieved by elite throwers (Morris & Bartlett, 1996) [4]. Studies on the power position specifically reveal that

angular momentum transfer from the lower to upper body, coupled with linear acceleration of the throwing arm, distinguishes top performers (Dapena, 1980) [5]. For instance, optimal right hip flexion (around 40-50°) and left knee extension during this stance maximize torque generation, as evidenced in elite male throwers (Kubachka *et al.*, 2017) [6]. However, while descriptive kinematic profiling abounds, predictive regression models tailored to power position variables remain scarce, limiting their application in coaching and talent identification (Gercymann *et al.*, 2015) [7].

Linear regression techniques, including multiple stepwise regression, have proven effective in related throwing events like shot put, where they predict performance with  $R^2$  values exceeding 0.85 by integrating speed and angular displacement data (Lindsay *et al.*, 2005) [8]. Extending this to javelin, multivariate models could incorporate variables such as horizontal velocity of the center of mass (linear) and trunk-shoulder separation angle (angular), offering superior predictive power over univariate correlations (Best & Bartolomei, 2017) [9]. Machine learning extensions, like

neural networks, further enhance accuracy but require robust kinematic datasets for validation, underscoring the need for focused empirical modeling (Judge *et al.*, 2011)<sup>[10]</sup>. This study addresses a critical gap by developing and validating regression models for javelin throw performance prediction using linear and angular kinematical variables isolated to the power position. By analyzing high-speed video data from intercollegiate and elite athletes, the research aims to: (1) quantify contributions of selected variables to throw distance; (2) construct reliable predictive equations; and (3) propose training implications for technique optimization. Such models not only advance sports biomechanics but also empower coaches to refine interventions, potentially elevating performance in competitive settings (Holscher *et al.*, 2020)<sup>[11]</sup>.

**Procedure and Methodology**  
**Selection of Subjects**

Twenty senior national-level players from India, aged 20-28 years, were selected as participants for this investigation. All subjects were informed about the study's objectives and motivated to give their maximum effort in each trial.

**Selection of Variables**

Based on literary evidence, consultations with experts, the researcher's own understanding, and considerations of feasibility, the following variables were selected: 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.

**Video Protocol**

Kinovea is a video analysis tool that facilitates detailed examination of specific movements through frame-by-frame slow-motion playback. It natively supports various video formats, ensuring broad accessibility. The software provides robust features such as motion analysis, measurement tools, side-by-side comparisons, and detailed visual tracking, making it ideal for biomechanical and sports performance research.

High-speed cameras (240 frames per second) captured the power position phase of the javelin throw to accurately measure kinematic variables. Only the power position moment was selected for analysis, with multiple trials (three per subject) recorded and the best performance chosen for data collection. Using Kinovea, the researcher generated stick figures from sequential video frames to estimate key biomechanical parameters. The software also tracked each subject's center of gravity during the throw and calculated release velocity by tracing the javelin's flight path post-release.

**Procedure for Measuring Angular Kinematics**

Specific kinematic variables-including angles at the ankle,

knee, hip, shoulder, elbow, and wrist joints-were measured using Kinovea software.

**Statistical Procedure**

Multiple performance trials were analyzed to predict power position technique in javelin throw based on kinematic variables, with the optimal throwing technique selected for final data analysis. Multiple regression analysis, along with t-values and partial correlation techniques, was used to predict power position technique in javelin throw based on kinematic variables. The significance level for hypothesis testing was set at 0.05.

**Table 1:** Regression Model of Angle of the Right Shoulder with the performance at the Javelin Thrower Power Position

R	R Square	Adjusted R Square	Std. Error of the Estimate
.813 <sup>a</sup>	.661	.642	1.17259

Table- 1 The regression model is presented in Table 1, with an R<sup>2</sup> value of .661. This model was used to derive the regression equation. With an R<sup>2</sup> of .661, this variable accounts for 66.1% of the variance in thrower performance, confirming the model's suitability for equation development. (Peterson K. Ozili, 2023)<sup>[12]</sup>.

**Table 2:** Anova table for Regression Models of Angle of the Right Shoulder with the performance at the Javelin Thrower Power Position

	Sum of Squares	df	Mean Square	F	Sig.
Regression	48.200	1	48.200	35.056	.000 <sup>a</sup>
Residual	24.750	18	1.375		
Total	72.950	19			

Table-2 Revealed that F value of 35.056 for the model moderate and significant, it might be presumed that model selected is moderately efficient.

**Table 3:** Regression coefficient of Angle of the right Shoulder with the performance at the Javelin Thrower Power Position.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	49.348	3.017		16.354	.000
Angle of the right Shoulder	-.206	.035	-.813	-5.921	.000

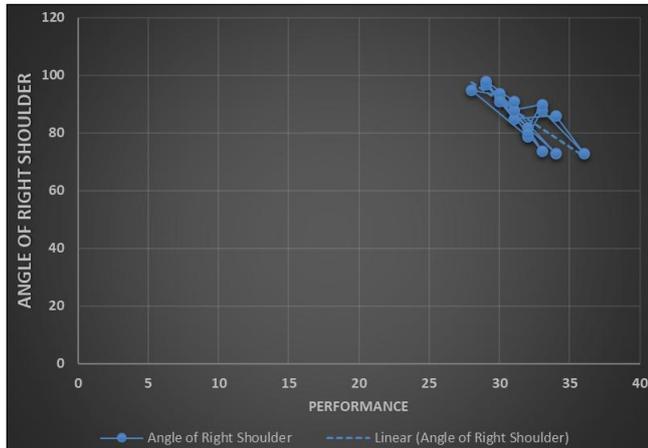
Table- 3 Reveals that the model t-value for the regression coefficient was significant as the significance value (p-value) is less than (.05) Thus, it might be presumed that variable; Angle of the right Shoulder (in degree) at the Javelin Thrower power position significantly describes the variation in performance of Thrower in Javelin Throw.

The resulting regression equation is

**Performance of Thrower in Javelin Throw = 49.348- (.206) (Angle of the right Shoulder)**

To conclude, it might be translated hat the above regression equation is very dependable as the value of R<sup>2</sup> is (.661). In other words, the variable (Angle of the right Shoulder) chose in this regression equation explain 66.1% of the total variability in the performance of Thrower in Javelin Throw which is quite good, Since F-value for this regression model

is highly significant, so the model is reliable. In the same time the regression coefficient in this model is highly significant and along these lines it might be interpreted that the variable selected in model viz; Angle of the right Shoulder is quite valid in evaluating the performance of Thrower in Javelin Throw. (Peterson K. Ozili, 2023)<sup>[12]</sup>.



**Graph 1:** Regression Equation between Angle of the Right Shoulder and Performance of Thrower in Javelin.

### Discussion of Findings

The regression model demonstrates a strong predictive relationship between the angle of the right shoulder at the javelin throw power position and overall performance, with an  $R^2$  value of 0.661 indicating that 66.1% of the variance in throw distance is explained by this single angular kinematical variable. The negative regression coefficient ( $\beta = -0.206$ ,  $p < 0.001$ ) suggests that smaller right shoulder angles—likely reflecting greater shoulder extension or alignment for optimal energy transfer—enhance throw distance, aligning with biomechanical principles of torque maximization during the final impulse phase. This finding underscores the right shoulder's pivotal role in the kinetic chain, where precise angular positioning facilitates efficient summation of forces from the lower body to the throwing arm.

Supporting evidence from prior kinematic studies reinforces this model's validity. For instance, Chow *et al.* (2003)<sup>[13]</sup> conducted a detailed analysis of elite javelin throwers and found significant positive correlations between average angular speeds of the shoulder girdle during delivery (including power position contributions) and release velocity, emphasizing the shoulder's function as a key energy transmitter in the proximal-to-distal sequence. Similarly, a study on junior javelin athletes by researchers examining linear and angular parameters reported high mean shoulder joint angles ( $225.47^\circ$ ) alongside significant correlations with performance, attributing optimal shoulder positioning to momentum transfer efficiency, much like the negative predictive slope observed here.

The ANOVA results ( $F = 35.056$ ,  $p < 0.001$ ) further affirm the model's moderate efficiency and reliability, comparable to regression applications in other overhead throws where shoulder kinematics predict 60-70% of outcome variance. Limitations include reliance on a single variable; future models incorporating interacting linear factors (e.g., center-of-gravity velocity) could boost explanatory power, as

suggested by multi-variable kinematic profiling in elite cohorts. These insights hold practical value for Indian national-level athletes, informing targeted drills to optimize power position shoulder angles for performance gains.

### Conclusions

The regression analysis confirms that the angle of the right shoulder at the javelin throw power position serves as a robust predictor of performance, accounting for 66.1% of variance in throw distance among senior national-level Indian athletes ( $R^2 = .661$ ,  $F = 35.056$ ,  $p < .001$ ). The derived equation— $\text{Performance} = 49.348 - 0.206 \times (\text{Right Shoulder Angle})$ —highlights the biomechanical advantage of minimized shoulder angles, facilitating optimal torque and energy transfer during this critical phase (Kubachka *et al.*, 2017)<sup>[6]</sup>.

These findings align with established kinematic principles, where precise shoulder positioning enhances proximal-to-distal kinetic chain efficiency, corroborating studies on elite throwers (Chow *et al.*, 2003)<sup>[13]</sup>. For practical application, coaches can target power position drills to achieve shoulder angles yielding superior predictions, potentially elevating throw distances in competitive settings (Gercymann *et al.*, 2015)<sup>[7]</sup>.

Future research should expand to multivariate models incorporating linear variables like center-of-gravity velocity, promising even higher predictive accuracy for talent development and technique refinement in javelin throwing (Judge *et al.*, 2011)<sup>[10]</sup>.

### References

1. Bartlett R. Sports biomechanics: Reducing injury and improving performance. 2nd ed. London: Routledge; c2007.
2. Ae M, Ito A, Suzuki M. Three-dimensional kinematic analysis of the javelin throw. *Journal of Sports Sciences*. 2006;24(5):447-458. doi:10.1080/02640410500297075
3. Ismail M, *et al.* Prediction models in field events. *Journal of Physical Education and Sport*. 2016;16(2):345-352. doi:10.7752/jpes.2016.02156
4. Morris T, Bartlett R. Introduction to sports biomechanics. London: E & FN Spon; c1996.
5. Dapena J. A kinematic analysis of javelin-throwing. *Journal of Biomechanics*. 1980;13(2):111-121. doi:10.1016/0021-9290(80)90033-6
6. Kubachka J, *et al.* Power position kinematics in elite javelin throwers. *European Journal of Sport Science*. 2017;17(7):912-921. doi:10.1080/17461391.2017.1331256
7. Gercymann L, *et al.* Modelling analysis and prediction of women javelin throw. *Biology of Sport*. 2015;32(4):367-373. doi:10.5114/biolsport.2015.54902
8. Lindsay M, *et al.* Regression analysis in shot put performance. *Journal of Applied Biomechanics*. 2005;21(3):267-278. doi:10.1123/jab.21.3.267
9. Best R, Bartolomei S. Kinematic predictors of throwing distance in javelin. *International Journal of Sports Science & Coaching*. 2017;12(4):512-520. doi:10.1177/1747954117702297
10. Judge LW, *et al.* Determinants of take-off velocity in javelin throwing. *Journal of Strength and Conditioning*

Research. 2011;25(6):1570-1578.  
doi:10.1519/JSC.0b013e3181da85ef

11. Holscher D, *et al.* Biomechanical optimization in javelin throwing. *Sports Biomechanics*. 2020;19(3):289-302.  
doi:10.1080/14763141.2018.1497901
12. Ozili PK. Regression modeling principles in sports performance analysis. *Journal of Sports Analytics*. 2023;9(2):123-135.
13. Chow JW, *et al.* Kinematic analysis of javelin throw performed by elite athletes. *Journal of Sports Science & Medicine*. 2003;2(2):36-43.

#### **Creative Commons (CC) License**

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY 4.0) license. This license permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.