INFLUENCE OF KINETIC FACTORS ON JAVELIN THROW PERFORMANCE

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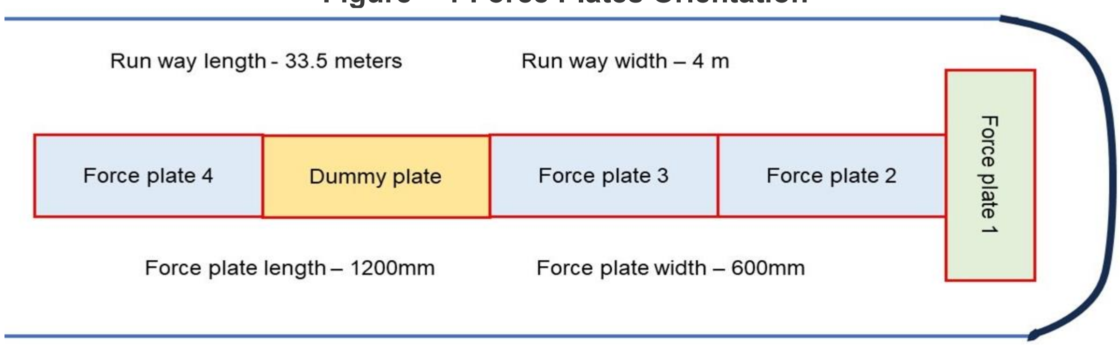
The purpose of the study was to find out the relationship of Javelin throw performance on peak vertical Ground Reaction Force (GRFv) at last third step, at penultimate step and at delivery step and release velocity at the instant of release. Twelve national level male javelin throwers performed six trials of javelin throw with adequate rest between trials. The Qualisys 3D mocap system were synchronized with four force plates to capture the delivery phase. The data were analyzed using Pearson product moment correlation followed by multiple linear regression. The javelin throw performance had a significant positive linear correlation with peak vertical GRF at last third step, at penultimate step, at delivery step and release velocity at delivery phase. The multiple linear regression revealed that peak GRFv at last third step was the predictor of javelin throw performance.

KEY WORDS: Peak Vertical Ground Reaction Force, Last Third Step, Predelivery Step, Delivery Step, Release Velocity

INTRODUCTION: Throwing the Javelin as a sport evolved from the everyday use of the spear in hunting and warfare. It was widely practised in Ancient Greece and incorporated into the Olympic Games in 708 BC as part of the pentathlon. The Javelin throw event for men and women was introduced in the modern Olympics in 1908 and 1932, respectively. The main objective of the javelin throw is to attain the greatest possible throwing distance. The men's Javelin was redesigned by moving the centre of gravity four centimetres forward to reduce the throwing distance to less than 100m in the year 1986. Jan Zelezny of the Czech Republic set the world record with a distance of 98.48 meters in 1996. The javelin throw has four phases: approach run, cross-over phase, release phase/delivery phase, and recovery phase/follow-through phase. Successful throws are characterized by an orderly progression of peak speeds at the hip, shoulder, and elbow from the onset of double leg support until release (Whiting et al., 1991). It is assumed that the horizontal momentum gained when the thrower touches the last left foot will be converted into a combination of vertical and horizontal upper-body movement. The closed kinetic chain power generation from the lower extremity and transmission to the end segment is the key to a better throw in Javelin (Morriss & Bartlett, 1996). The release velocity, angle of release, angle of attitude, angle of attack and height of release during the Javelin throw delivery phase determine the javelin performance (Thotawatha & Chandana, 2021). The release velocity is crucial for Javelin throw performance (Bartonietz, 2000; Krzyszkowski & Kipp, 2021). The previous studies focussed on velocity of release, angle of release, height of release, attack angle, attitude angle, contributions of body segments responsible for effective release, and simulation of javelin flight using aerodynamic data for improving throwing performance (Hubbard & Rust, 1984; Chiu, 2009). The main objective of the javelin throw is to generate power at the instant of release to maximise the release velocity. The power at the delivery phase is generated from the sequence of movements in each phase by the thrower, such as approach run (initial momentum), cross-over step, and delivery phase in tandem with a principle of closed kinetic chain. Planting the foot from the cross-over and delivery steps facilitates energy transfer with sequential muscle activation (Koheler & Witt, 2023). Very few research conducted so far assessing and quantifying the peak GRFv at last third step, penultimate step, and delivery step and their influence on Javelin throw performance. The purpose of the study was to find out the relationship of peak GRFv at the last third step, penultimate step, and delivery step (The vertical GRF only measured for the purpose of the study), as well as the release velocity at the instant of release of Javelin at delivery phase on Javelin throw performance.

METHODS: Twelve national-level male javelin throwers were chosen as participants representing various states of India. The age of the participants ranged between 20 and 27 years. All were right-hand throwers; each participant signed the informed consent form and expressed willingness to participate in this study. The demographic profile the selected participants are given as follow: mean body height 181.25 cm (±3.28), mean body weight 84.67 kg (±4.14), mean chronological age 23.67 years (±2.10) and mean training age 5.17 years (±0.94). The javelin throw performance (distance of throw) was considered as the dependent variable and peak GRFv at the last third step, penultimate step, delivery step, and release velocity were considered as independent variables in this study. The release velocity means the resultant velocity of the Javelin at the point of release. The data were collected at the Centre of Excellence in Biomechanics cum High Performance Centre (CEB-HPC), Tamil Nadu Physical Education and Sports University, Chennai, India. Each participant was asked to go far adequate warmup before the trials. Each participant was given six trials, and the best of six trials was taken for final data analysis to quantify the release velocity of the Javelin. The participants used their style of grip, approach run, and cross-over strides (three or five). Qualisys mocap system was used to capture the Javelin throw performance at the instant of release and quantify the release velocity of the Javelin at the instant of release during the delivery phase. Twelve Qualisys Arqus (A12 Infra-red) cameras were positioned, and two Miqus video cameras were used to capture the video (185 fps at HD resolution) at the Javelin Performance delivery phase. The calibration was done using an L frame placed at the centre of the capturing volume and a 120mm calibration wand. The Arqus cameras captured the delivery phase at 300 fps with a resolution of 12MP. The 41 (14 mm passive markers) sports marker system was used to capture the 3D kinematic data with the use of QTM software. The maximum distance thrown by the thrower's data was further processed to quantify the release velocity using Visual 3D software. The 3D Kistler force plates were synchronised with Qualisys 3D mocap system using sync unit. As illustrated in Figure 1, Four Kistler force plates (Model: 9287CA; Size 1200mm / 600mm) were mounted to collect the peak GRFv (Only Z force) at the last third step, penultimate step, and delivery step. The sampling frequency of the force plate was 3000hz. The collected data were analysed using Pearson product-moment correlation, and stepwise multiple linear regression was used to estimate the individual contribution of variables. The collinearity of independent variables was verified based on a variance inflation factor threshold of 10 (Tabachnick, Fidell, & Ullman, 2013). A statistical analysis was performed using SPSS Statistics for Windows, version 20.0, with the significance level set at $p \leq 0.05$.

Figure – 1 Force Plates Orientation



RESULTS:

Table – 1 Linear Correlation

Variables	Mean (SD±)	Javelin TP	GRFv LTS	GRFv PS	GRFv DS	Release Vel.
Javelin TP	76.74 (±2.90) m	1.00	.96**	.91**	.88**	.89**
GRFv LTS	4320.83 (±229.08) N		1.00	.91**	.90**	.89**

GRFv PS	3162.50 (±165.31) N			1.00	.85**	.81**
GRFv DS	3670.83 (±215.80) N				1.00	.79**
Release Vel.	26.72 (±1.14) m/s					1.00

Correlation is significant at the 0.01 level (2-tailed).**

Javelin TP – Javelin Throw Performance; LTS-Last Third Step; PS-Penultimate Step; DS-Delivery Step; Release Vel.- Release Velocity

The results of the study (table-1) revealed that javelin throw performance had a significant positive correlation with peak GRFv at the third last step 96% (r=0.96), peak GRFv at the penultimate step 91% (r= 0.91), peak GRFv at delivery step 88% (r=0.88) and release velocity at delivery phase 89% (r=0.89) at 0.01 level of significance. Further, figure-2 depicts the linear positive association between javelin throw performance and selected variables.

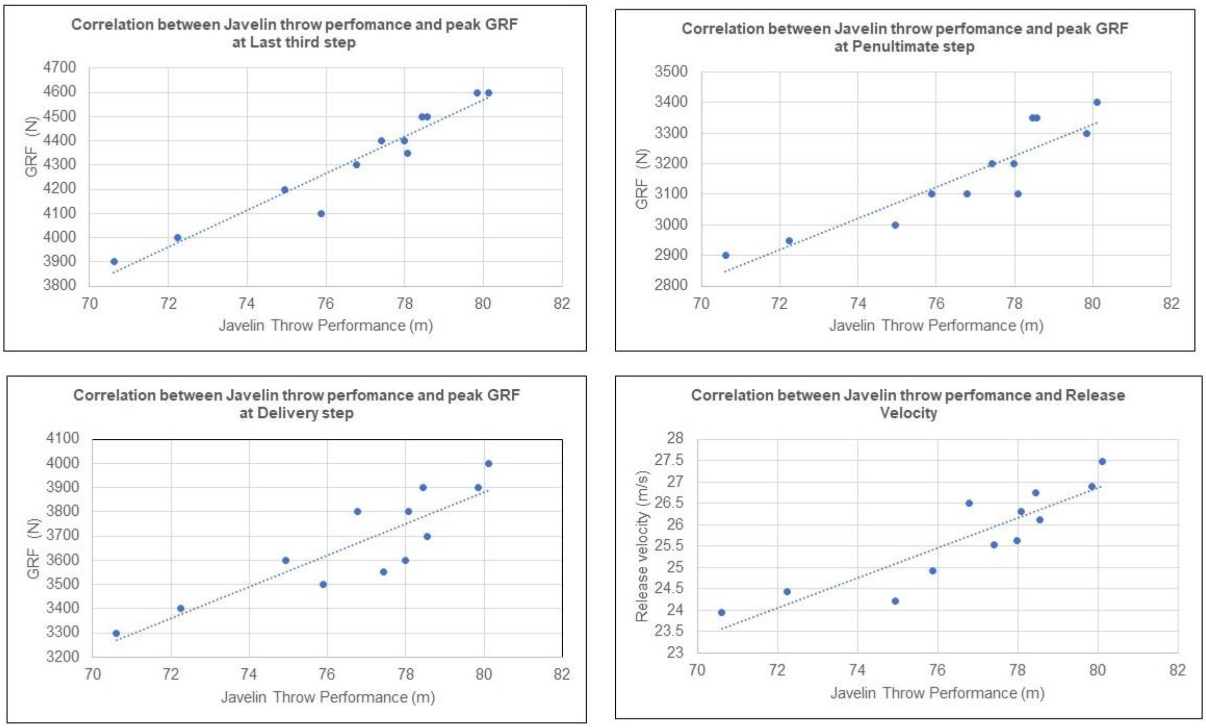


Figure – 2 Scatter diagram showing relationship between javelin throw performance and the selected variables

Table – 2 Model Summary

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	**Sig. F**	**Durbin-Watson**
1	.964[a]	.930	.923	.806	.000	2.104

a. Predictors: (Constant). GRFv at Last Third Step
b. Dependent Variable: Javelin Distance

Table – 3 Coefficients

Model		**Unstandardized Coefficients B**	**Unstandardized Coefficients Std. Error**	**Standardized Coefficients Beta**	**t**	**Sig.**	**Collinearity Statistics Tolerance**	**Collinearity Statistics VIF**
1	(Constant)	23.878	4.591		5.201	.000		
	GRFv at Last Third Step	.012	.001	.964	11.529	.000	1.000	1.000

Multiple linear regression analysis demonstrated that GRFv at last third step (R^2=0.930; p=0.001) was the predictor of Javelin distance entered into the model (Table-2) and all other variables were excluded from the model. The Durbin-Watson value is 2.104, which indicates no significant autocorrelation. In addition, the VIF value is less than 10 (Table 3), which reveals there is no multicollinearity. Further, the results of ANOVA (F=132.918) confirmed that the model is significant.

DISCUSSION: This study investigated the contribution of different biomechanical variables on Javelin performance. The main findings are: The javelin performance had a significant correlation with all independent variables, and GRF at the Third stride may explain 93% of the variance in Javelin performance. Murakami et al. (2017) found a significant positive correlation between the throwing distance and initial velocity of javelin release. Further, the findings of Murakami et al. (2006) and Campos et al. (2002) corroborate with the present study's findings of linear correlation that Javelin throw performance is highly influenced by release velocity. The findings of the present study show that the javelin thrower attains the peak GRFv at the third last step (the highest force), second highest peak GRFv force at the delivery step (85 to 90% of the force of the last third step) and least force at penultimate step (65 to 70% of the force of last third step. Hurrion et al. (2002) reported that the peak force at the delivery step was greater than the previous foot contact, which supports the findings of the present study. We must acknowledge certain limitations of our study. Firstly, our sample size was small. Secondly, while previous research indicates many variables influencing javelin performance, our study only considered a few, which may have limited our findings.

CONCLUSION: The javelin throw performance is significantly influenced by the peak GRFv at the third last step, the penultimate step, the delivery step, and the release velocity at the delivery phase. The peak GRFv at the last third step is the better predictor of javelin throw performance. Hence, it is of utmost importance to refine the throwing technique, strengthen relevant muscle groups, and implement specific velocity-focused drills and exercises based on closed kinetic chain principles.

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