BIOMECHANICAL ANALYSIS OF ELITE FEMALE JAVELIN RELEASE CHARACTERISTICS

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The distance covered in a javelin throw is the result of numerous factors and there are many people who have researched and analyzed javelin throwing performances during competition (Ariel, 1973; Gregor, 1985; Komi & Mero, 1985; Miller & Munro, 1983; Terauds, 1975, 1978; Witchey, 1973). This research focused on the instant of release with particular emphasis on the magnitude of the release velocity, velocity of the angle, angles associated with the javelin, and the release height. The body segment contributions responsible for producing the release conditions have also been assessed. In addition, other researchers have simulated the javelin flight using experimental aerodynamic data in order to improve performance. (Hubbard & Rust, 1984; Hubbard & Alaways, 1987; Soong, 1975). From the reports, the most important factor in the javelin throw is the release velocity. There are many throwers, however, who obtain different distances using similar release velocities, attitude angels and angles of attack. Furthermore, the longest distances are sometimes not achieved using the greatest release velocity. Komi (1985) found this circumstance to be especially true in the case of elite female javelin throwers. Another factor is that throwers do not usually achieve the same distance consistently in a single competition. It seems the initial conditions, mentioned previously, would significantly influence the distance of the javelin throw; thus it is important to continue to investigate these factors which determine javelin distance.

The purpose of this study was to investigate several selected release characteristics of techniques used in the javelin throw to determine which of these characteristics was significantly related to the

javelin distance for the elite female javelin throwers, and also among interindividual elite female throws.

Methods

Data Collection

Subjects: The subjects were 12 finalists in the women's javelin throwing at the 1984 Olympic Games in Los Angeles. The films were obtained through a project directed by the I.O.C. Medical Commission.

Filming Protocol: A LoCam camera, filming at a nominal rate of 200 frames per second, was used to record the performance of the subjects. The camera was placed at a distance of 24 m from the mid-line of the javelin throw runway, and the optical axis of the zoom lens was oriented perpendicular to the principal plane of motion.

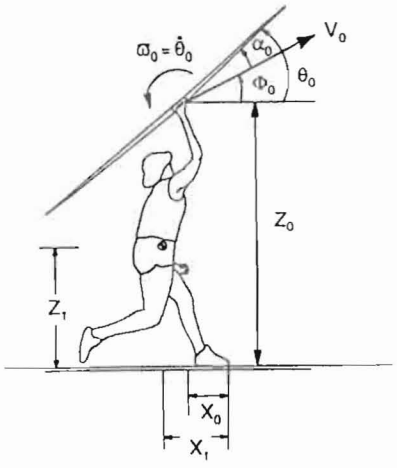
Data Reduction and Analysis

The best throwing trials were selected from the top 8 athletes. The throwing distance exceeded 60 m. An additional four trials in which the shortest throwing distance was six meters less than each athlete's best trial were also selected for analysis. There was no significantly different location of the final foot position between two trials of an athlete. Each of the selected trials was digitized with the aid of a Vanguard Sumagraphics Digitizer linked on-line to a laboratory micro-computer. Every other frame in each trial was digitized.

The x,y coordinates of 21 points defining the configuration of a 14-segment model of the human body plus 4 points on the javelin were recorded for each frame analyzed. The coordinate data were smoothed by a digital filtering technique, cut off frequency was 6 Hz. These data were then used as input to a computer program designed to calculate the various parameters and plots.

Parameter Model

Figure 1 shows several kinematic parameters for the javelin and selected body segments at release which are of special importance in this study. These parameters are from the film plane.



ϕ_0 = release angle; θ_0 = attitude angle; $\alpha_0 = \theta_0 - \phi_0$ = angle of attack; ω_0 = angular velocity; z_0 = height of release; z_i = cm. vs. grnd.; x_0 = hand vs. toe; x_i = cm. vs. toe.

Fig. 1. Parameter Model of Release

RESULTS AND DISCUSSION

Linear and Angular Data of the Javelin

Table 1 contains the values for release resultant velocity, vertical release velocity, and horizontal release velocity. The subjects had significantly different vertical and horizontal release velocities, but all had relatively similar release resultant velocities. The vertical and horizontal velocities had also been increased disproportionately, so that the angle of the resultant velocity was always different during the final foot contact. This change in resultant velocity would influence the attitude of the javelin, the attitude angle, and increase the javelin oscillations as well. Prior research has focused mainly on the instantaneous parameters associated with the release characteristics of the javelin throw. In future studies, a more detailed analysis of the complete throwing motion should be carried out.

In Table 2, throwing distances of 60 m or over were associated

with the following data: the release angle occurred at 38.6 deg. (+/-3.7), the attitude angle at 39.4 deg. (+/- 3.9), and the angle of attack was at 0.8 deg. (+/-2.4). Recorded distances of less than 60 m had the following data in common: a release angle of 40 deg. (+/-2.1), an attitude angle of 41 deg. (+/-2.5), and angle of attack at 1 deg. (+/-3.6). Comparatively, these angles are not statistically significant and there is no distinguishable interindividual variation among the distances obtained from different throws of the same elite female athlete. However, the angles themselves are larger than those recommended by Terauds (1978). He indicated that the optimal release angle would be somewhat lower and that there would be less of a difference between attitude and release angles. He further suggested that the performance angle would be smaller when compared to the peak performance angle associated with the lower throws found in Table 2. Consequently, optimal release angle, attitude angle and angle of attack should be smaller in the elite female javelin thrower.

Table 1

Subject and Velocity of Javelin at Release

Subject	Nation	Velocity of Javelin (m / s)									Analized (m)
		Horizontal			Vertical			Resultant			
		i	ii	iii	i	ii	iii	i	ii	iii	
Sanderson,T.	GBR	8.22	12.90	18.06	1.54	7.55	12.28	8.36	14.95	21.84	69.56
Liilak, T.	FIN	7.46	12.34	18.65	1.38	9.37	14.33	7.53	15.49	23.52	69.00
Whitbread, F.	GBR	8.35	11.55	15.51	0.20	8.69	15.07	8.35	14.46	21.62	67.14
Laaksalo, T.	FIN	7.64	11.37	16.41	0.94	9.02	14.37	7.70	14.51	21.81	66.40
Solberg, T.	NOR	8.43	13.48	17.81	0.29	7.20	12.78	8.43	15.28	21.92	64.52
Thyssen, I.	FRG	7.71	12.33	16.93	1.26	9.68	14.97	7.81	15.67	22.60	63.26
Smith, K.	USA	7.71	13.22	17.54	0.57	7.31	12.83	7.73	15.10	21.73	62.06
LILLAK, T.		7.21	12.18	18.92	1.50	8.93	14.79	7.37	15.10	24.01	61.12
LAAKSALO, T.		7.71	11.15	16.63	0.27	8.62	14.02	7.71	14.09	21.75	58.42
SMITH, K.		7.42	11.82	16.77	0.11	5.74	13.25	7.42	13.14	21.37	55.92
THYSSEN, I.		7.08	11.92	16.12	0.84	9.83	14.57	7.13	15.45	21.72	55.84

i. at the beginning of the final foot contact.
ii. 0.04 s before the release of the javelin.
iii. at the release moment.

Table 2
Angular Parameters of the Javelin at Release

Subject	Release angle (deg.)			Attitude angle (deg.)			Angle of attack(deg.)			Angular velocity (deg./s)		
	i	ii	iii	i	ii	iii	i	ii	iii	i	ii	iii
Sanderson,T.	10.6	30.3	34.2	35.5	34.5	34.9	24.9	4.2	0.7	7	-8	-11
Lillak, T.	10.5	37.2	37.5	38	37.2	37.7	27.5	0	0.2	9	-11	-14
Whitbroad, F.	1.4	37	44.2	45.3	45.9	46.5	43.9	8.9	2.3	-11	-16	-13
Laaksalo, T.	7	38.5	41.2	37.5	38.8	38	30.5	0.3	-3.2	-25	12	21
Solberg, T.	2	28.1	35.7	34.3	35.6	36.4	32.3	7.5	0.7	-32	-19	-21
Thysson, I.	9.3	38.1	41.5	44.4	42.4	41.6	35.1	4.3	0.1	17	26	20
Smith, K.	4.2	28.9	36.2	39.5	40.1	41	35.3	11.2	4.8	-39	-29	-26
M	6.4	34	38.6	39.2	39.2	39.4	32.8	5.2	0.8	-11	-6.4	-6.3
SD	3.9	4.7	3.7	4.2	4	3.9	6.2	4.2	2.4	22	19	19
LILLAK, T.	11.8	36.2	38	35.6	36	38.6	23.8	-0.2	0.6	17.5	-28	-81
LAAKSALO, T.	2	37.7	41.4	36.6	37.9	40.3	34.6	0.2	-1.1	-30	-16	-65
SMITH, K.	0.8	25.9	38.3	40.1	41.8	44.6	39.3	15.9	6.3	-38	-24	-72
THYSSEN, I.	6.8	39.5	42.1	45.8	43.3	40.4	39	3.8	-1.7	33	39	74
M	5.4	34.8	40	39.5	39.8	41	34.2	4.9	1	-4.4	-17	-36
SD	5	6.1	2.1	4.6	3.4	2.5	7.2	7.5	3.6	34.9	39.5	73.6

As one looks through Table 2, significant differences in the angular velocities between throws become apparent, even though their respective attack angles are very small and there is little difference between them. From these results, one can conclude that the angular velocity absolutely increased (either negatively or positively, with the clockwise direction being positive) and the distance of the throw decreased. Evidently there is a significant relationship between the distance covered in a javelin throw and the release angular velocity ($R = 0.70$, $p < 0.01$) (See Figure 2). The initial angular velocity of the javelin can either increase the drag or decrease the lift during a javelin flight. This may be one of the most important reasons why some female athletes can not achieve longer throwing distances using faster release velocities.

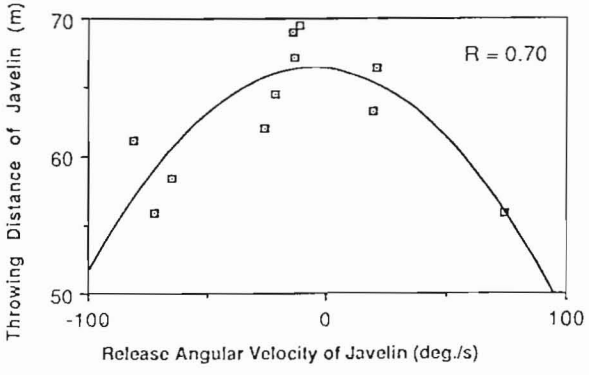


Fig. 2. Relationship Between Distance and Angular Velocity

Two complex questions arise in this study. The first is why the angle of attack decreased as angular velocity increased? The second question is why a large variation exists in the angular velocities of the subjects while their angles of attack are relatively similar. One of the most important problems associated with the javelin throw concerns the release hand. The problem itself is dependent upon the direction of the action force vector and the moment of the acting force. (See Figure 3). The arm motion tends to be circular, and the fingers have to be removed from the grip without a pull down or turning effect on the javelin at the precise moment during the release. Attention must be paid to the changes in the final phase of throw. Further research should be conducted in this area to find the answers to such questions.

In this study, certain throws were classified as either good or bad. In a good throw, a javelin traveled approximately seven to eight meters farther than the distance covered in a bad throw. A possible explanation for why this seven to eight meter difference exists might be found in the actual mechanics involved in the javelin release.

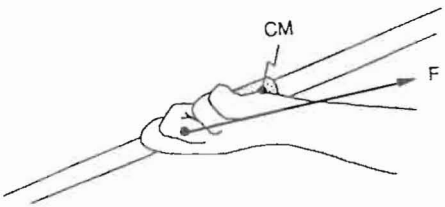


Fig. 3. CM. of Javelin and Acting Force Vector

From Tables 1 and 2, it should be noted that there is a relatively similar release velocity level among the elite female athletes, but each has a different level of javelin control especially in the direction of force action. As a result each of the subjects possess a different angular velocity with some subjects having an unsteady controlling ability while others do not.

The greatest difference between good and bad throws is in the angular velocities obtained form interindividual comparison (Tables 1

and 2). After throwing several times in one competition, the release velocity did not differ much among the elite female athletes; however, there was a significant difference in angular velocity. It is clear that one cannot throw farther using only a greater release velocity. From the data, Lillak, T. threw 69.00 m at 23.50 m/s, the angular velocity of the javelin was -14 deg/s. When the velocity of the javelin increased to 24.01 m/s, the distance covered dropped to 61.12 m. The problem was the angular velocity was now -81 deg/s.

The angular velocity is a result of throwing during the final foot contact. The difference in results is due to the different hand path and acting force. The path of the body segments also varied among different trials of the same athlete. The typical characteristics of the javelin throw, as shown in Table 3, are the last step, the height of release position, and the horizontal distance between the release point and toe. The parameters varied from athlete to athlete in the same competition.

Table 3

Interindividual Position Parameters of Body at the Release

Subject	Lst. Step Length (m)	Hand vs. Toe vert. Dist. (m)	Hand vs. Toe Horiz. Dist. (m)	CG. vs. Toe Vert. Dist. (m)	CG. vs. Toe Hor. Dist. (m)	Throw Distance (m)
Lillak, T.	1.85	1.91	0.28	0.87	0.44	69
	1.93	1.79	0.38	0.79	0.53	61.14
Laaksalo, T.	1.91	1.79	0.2	0.87	0.5	66.4
	1.95	1.72	0.29	0.86	0.52	58.42
Thyssen, I.	1.84	1.9	0.18	0.89	0.4	63.26
	1.78	1.83	0.21	0.84	0.42	55.84
Smith, K.	1.23	1.73	-0.16	0.82	0.18	62.06
	1.2	1.68	-0.22	0.8	0.21	55.92

Summary

From this study it can be concluded that: (1) The release velocity is still the most important factor in the javelin throw, but the angular velocity must be taken into consideration as well for it significantly influences javelin flight. (2) The greatest difference between a good throw and a bad throw is the angular velocity. (3) The throwers must consider the total procedure of the javelin throw and keep the direction of the javelin constant during the final phase. (4) The athletes should be encouraged to maintain a constant technique throughout all phases of the javelin throw. This aspect should be emphasized as one of the most important factors in their training. These performances, of course, are not limited to a single plane. Future research should be conducted using 3D analysis of the javelin throw in order to obtain more detailed information.

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