KINEMATIC ANALYSIS OF ELITE JAVELIN THROWERS

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Research on various aspects of the throwing motion has indicated it to be a very complex movement (Atwater, 1979). Certain kinematic parameters appear to be common determinants of successful performance regardless of the nature of the throwing task. Under ideal conditions (i.e., ignoring air resistance and the type of implement being thrown) the path, and hence distance thrown, is determined by the angle, height and velocity of release. Such an ideal analysis needs some modification for situations in which aerodynamics are considered. Since the release phase of the javelin throw encompasses these common throwing components as well as obvious aerodynamic influences, quantification of release characteristics which establish the initial conditions of flight is important.

The majority of reported data concerns kinematic parameters calculated from high speed film taken during competition and has focused on height, angle and velocity of the javelin at release (Miller & Munro, 1983; Terauds, 1978; Wilson, 1979). These studies have been cross-sectional in nature, analyzing selected athletes at specific track meets and limiting the population of subjects to male throwers. The United States Olympic Committee has sponsored longitudinal biomechanical analysis of elite male and female javelin throwers since March of 1982. The purpose of the present study was to assess the technique of America's top javelin throwers by examining kinematic measures which affect throwing distance. A secondary goal was to provide normative data on elite throwers.

METHODS

Data Collection and Analysis

Under the auspices of the.USOC's Elite Athlete Project, eight of America's top javelin throwers (Table 1) were filmed over a fifteen month period at major national competitions and selected throwing clinics (Table 2). All film data were collected using either a 16 mm Locam (Redlake Corp., Campbell, CA) or Photosonics 1P (Instrumentation Marketing, Inc., Burbank, CA) camera operating at 100 fps. The actual frame rate was verified by timing lights internal to each camera. While the athletes were filmed from both a side and front view, data in the present study were taken from the side view films to analyze movement in the sagittal plane. The side view camera was positioned 16-18 m from the center of the javelin runway on the athletes' throwing-arm side. This orientation permitted viewing the crossover, final foot plant and release of the javelin. A meter stick was filmed at the beginning and end of each test session and served as a reference multiplier. The subjects' name, trial number, distance thrown, date and time were also recorded.

Twenty-eight trials were selected for analysis (n=15 for men, n=13 for women). Films were rear projected onto a frosted glass screen using a Vanguard M-16C projector, and digitized using a Graf/Pen Sonic Digitizer (Science Accessories Corp., Southport, CN) interfaced with a DEC 11/23 minicomputer (Digital Equipment Corp., Maynard, MA). Ten points were digitized for each trial at the moment of release, which was defined as the first frame after the javelin left the hand. The six kinematic parameters calculated were release angle, attitude angle, attack angle, height of release, front foot to foul line distance, and velocity of release (Figure 1). Release velocity was determined by averaging instantaneous velocities for the 30 ms interval just after release.

Multiple linear regression and cross-correlation routines were used to assess differences between kinematic parameters. T-tests were used to determine if the means between males and females significantly differed for each parameter. The two groups differed significantly ($p<.05$) on velocity of release and height of release. The other four parameters - release angle, attitude angle, attack angle and front foot to foul line distance - showed no significant differences between males and females and, therefore, were analyzed as a combined population.

TABLE 1 SUBJECT INFORMATION

	Subject ID	Height (m)	Weight (kg)	Throws Analyzed
	TP	1.88	84.9	6
MEN	BR	1.93	109.0	5
	RE	1.88	114.0	4
	KS	1.68	55.0	3
	KC	1.85	75.0	2
WOMEN	LH	1.70	65.9	3
	PK	1.74	72.7	3
	SH	1.73	62.7	2

Total Number of Throws Analyzed 28

TABLE 2 FILMING INFORMATION

Throwing Clinic	Los Angeles, CA	3-13-82	Men
UCLA-Pepsi Track Meet	Los Angeles, CA	5-16-82	Men
Throwing Clinic	Los Angeles, CA	12-29-82	Women
Throwing Clinic	Northridge, CA	3-5-83	Men & Women
TAC National Championships	Indianapolis, IN	6-18/19-83	Men & Women

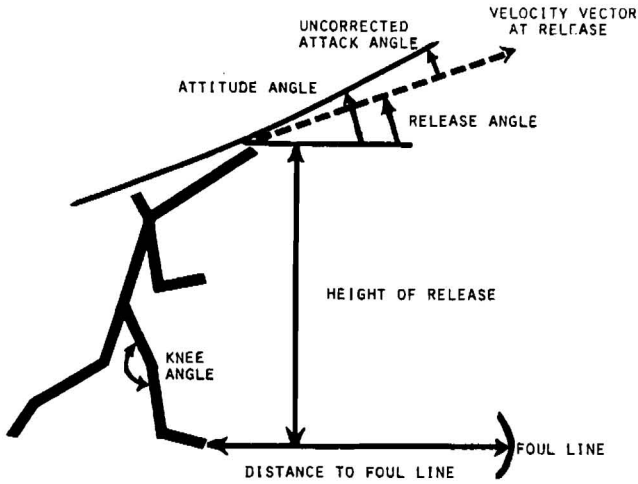

FIGURE 1. KINEMATIC PARAMETERS AT RELEASE

The following six parameters were calculated at release for each javelin throw: (1) release angle - the angle between the velocity vector and a horizontal reference; (2) attitude angle - the angle between a line joining the tail and the tip of the javelin and a horizontal reference; (3) attack angle - the difference between the release and attitude angles; (4) height of release - the vertical distance between the front of the javelin hand grip to the ground; (5) foot to foul line distance - the horizontal distance from the toe of the lead (plant) foot to the foul line; (6) velocity of release - the magnitude and direction of the javelin's velocity at release. Release velocity was determined by averaging instantaneous velocities for the 30 ms interval just after release.

Limitations

Analysis in this project was limited to a single plane with the concession that overarm throwing is a three dimensional movement. This, of course, applies to both the arm of the thrower as well as the orientation of the implement (javelin) being thrown. We evaluated only legal throws, and selected parameters for analysis that are generally reported to be related to throwing distance.

Additionally, it should be recognized that the true angle of attack is the acute angle between the attitude of the javelin and the relative air flow vector around the javelin (Miller & Munro, 1983). In the strictest sense the relative air flow at release cannot be measured during competition. Therefore, our working definition of attack angle is limited, but comparable to the definition used by Miller & Munro (1983) as an "uncorrected angle of attack".

TABLE 3

COMPARISON BETWEEN MALE AND FEMALE

RELEASE CHARACTERISTICS

Parameter	Men	Women
Distance (m)	84.6 (3.5)	55.0 (4.6)
Velocity of Release (m/s)	29.3 (1.6)	21.8 (1.3)
Attack Angle (deg)	8.0 (2.4)	7.5 (5.7)
Release Angle (deg)	30.9 (2.2)	32.7 (3.6)
Attitude Angle (deg)	39.0 (2.5)	40.1 (3.6)
Height of Release (m)	2.06 (0.11)	1.79 (0.15)

Mean (S.D.)

RESULTS AND DISCUSSION

The primary purpose of this study was to examine kinematic parameters which affect throwing distance in elite javelin throwers. Mean scores for the six parameters examined are listed in Table 3. Several authors have indicated that, excluding aerodynamic considerations, the distance a javelin travels is determined essentially by its velocity, height and angle at release (e.g., Hay, 1978; Attig, 1981). The relative contribution made by each of these variables is still a matter of debate. We therefore focused our attention on these kinematic variables separately.

Release Velocity

Previous studies have indicated that the distance a javelin will travel is primarily dependent upon the magnitude of velocity at release (Hay, 1978; Ikegami et al. (1981). The average release velocity in the present study was 29.3 m/s for men and 21.8 m/s for women. Terauds (1975,1978) and Miller & Munro (1983) reported release velocities for male throwers in the range of 25-31 m/s.

Terauds (1978) reported a correlation of r=0.72 between release velocity and distance for nine throws (mean = 84.98 m) at the 1976 Olympic Games and Ikegami et al (1981) found a value of r=0.99 for seven intermediate throwers (mean = 59.31 m). In the present study, positive yet statistically nonsignificant correlations were found between release velocity and the actual distance thrown for male and female populations considered separately. The correlations between release velocity and potential distance were higher than those for the actual distance, but were still not significant.

Height of Release

Height of release has been identified as an important parameter in determining throwing distance (Attig, 1981; Hay, 1978). In the present study however, correlations between release height and distance, as well as release height and other kinematic parameters, were not significant for either male or female populations. The average height of release for men was 2.06 m, which is consistent with the 2.08 m and 2.02 m reported by Miller & Munro (1983) and Terauds (1978), respectively. Release height averaged 1.79 m for women. There was a significant ($p<.05$) correlation between release height and the throwers' body height for both men ($r = 0.68$) and women ($r = 0.78$). These results are in agreement with Terauds (1978) who found that release height correlated well with the height of four male athletes ($r = 0.72$) but not with any other kinematic parameter.

Several coaching articles (e.g., Tucker, 1975) encourage the thrower to release the javelin as high as possible and directly over the head. When front view films from the present study were examined qualitatively, both men and women exhibited lateral trunk flexion away from the throwing arm and apparent full extension of the throwing arm at release (c.f., Atwater, 1979). These observations suggest that release height is a function of both body height and degree of lateral trunk flexion.

Angle Parameters

While most studies on javelin throwing have discussed the various angles associated with release, there has been little agreement on the definitions and terminology used (e.g., Paish, 1980; Witchey, 1973). Nor is there agreement on the values needed to optimize performance. In the present study, the attitude, release and attack angles were measured in an effort to better understand their effect on throwing distance.

The attitude angle (i.e., orientation of the javelin with respect to right horizontal) averaged 39.6° which is consistent with the 40.4° found by Ikegami et al (1981). Considerable bending in the javelin was observed at release and was considered due, in part, to the forces exerted on the javelin by the thrower and to the flexibility of the implement.

Angle of release (i.e., angle formed by the velocity vector with respect to the right horizontal) ranged from 25.7° to 40.3° and averaged 31.8°. These values are in agreement with previous reports of release angle ranges (24°-37°, Wilson (1979); 29.5°-34.2°, Ikegami et al (1981); 28.5°-37.5°, Terauds (1978)) and means (32.9°, Ikegami et al (1981); 34.1°, Terauds (1978)). Terauds (1978) also reported a correlation of r= 0.40 between release angle and distance thrown. In the present study, there were no significant correlations between angle of release and actual distance nor between angle of release and potential distance.

Angle of attack averaged 7.8° which is slightly higher than the 6.88° and 4.3° degrees reported by Terauds (1975,1978) but consistent with the 7.5° of Ikegami, et al (1981). No significant correlations were found between either attack angle and actual distance or attack angle and potential distance in the present study. Terauds (1978) indicated that a zero attack angle is favorable, citing longer throws associated with this value.

CONCLUSIONS

The results of this study suggest that no single kinematic parameter taken in isolation (e.g., release velocity) can predict distance thrown. Distance probably results more from a complex interaction between several different parameters, as well as the unknown wind factor. Women compared favorably with men regarding attack, release and attitude angles, but differed on release velocity and release height, due in part to body size and strength.

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