ASSOCIATIONS BETWEEN JAVELIN THROWING TECHNIQUE AND AERODYNAMIC DISTANCE

Steve Leigh[1], Hui Liu[2], and Bing Yu[1]

Center for Human Movement Science, The University of North Carolina at Chapel Hill, Chapel Hill, NC, USA[1]
Sports Biomechanical Laboratory, Beijing Sports University, Beijing, China[2]

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INTRODUCTION: The javelin is the most aerodynamic of the four track and field throwing implements. It is twenty times more aerodynamic than the discus (Hubbard, 1984). The official distance of a throw is measured by the meet officials. The vacuum flight distance is determined by the release parameters and the range equation. The aerodynamic distance is the distance gained (where official distance is greater than vacuum flight distance) or lost (where official distance is smaller than vacuum flight distance) due to aerodynamic factors that affect the flight (Hay & Yu, 1995). The ability to gain aerodynamic distance may be the differentiating factor between athletes with near-maximal release speeds and vacuum flight distances. It may be possible for a javelin thrower to increase their aerodynamic distance independently of other performance variables, such as release speed. A javelin throwers technique determines the release parameters of the javelin, which determines the aerodynamic distance. The purpose of this study was to determine which technique variables are associated with greater aerodynamic distances.

METHODS: Sixty two competitive trials of 32 male and 30 female javelin throwers were recorded at 60 frames/second with two HDDV camcorders placed parallel and perpendicular to the throwing direction. Twenty one body landmarks and the tip, tail, and centre of mass (COM) of the javelin were digitized for each trial. Three-dimensional (3-D) coordinates were calculated from the two camera views using the Direct Linear Transformation procedure.
The release parameters of the javelin were calculated from the 3-D coordinate data of the javelin at release as described by Best et al. (1993). Release speed is the magnitude of the javelin velocity vector at release. Release angle is the direction of the javelin velocity vector at release. Inclination angle is the orientation of the javelin with respect to the horizontal. Angle of attack is the angle between the release angle and the inclination angle. Official distance was recorded for each throw and the partial distances were calculated as described by Hay & Yu (1995). Knee, hip, leg, trunk, shoulder, and elbow joint angles were calculated from the 3-D coordinate data of the body landmarks. Speed and timing variables were calculated using critical instants of right foot down, left foot down, and release and the 3-D coordinate data of the body landmarks. The critical instants enabled meaningful inter-athlete comparisons to be made.
Males and females were analyzed separately to reduce confounding influences. Cross-sectional correlation and stepwise multiple regression analyses were performed to determine the relationships between the technique variables and aerodynamic distance. Commonality analyses were performed to investigate interrelationships among the technique variables. A type I error rate of 0.1 was chosen to indicate statistical significance.

RESULTS: For female javelin throwers greater aerodynamic distances were correlated with a more extended right elbow at right foot down ($p < 0.01$). A linear combination of javelin inclination angle at release and right elbow flexion angle at right foot down accounted for 26% of aerodynamic distance variability ($F = 4.792$, $p = 0.017$). Commonality analyses suggested some shared variance between technique variables (Table 1).
For male javelin throwers greater aerodynamic distances were associated with: more shoulder adduction at left foot down, a more extended right elbow at release, and a lower javelin inclination at left foot down ($p < 0.05$). A linear combination of release angle and right

knee angle at left foot down accounted for 26% of aerodynamic distance variability ($F = 4.996$, $p = 0.014$). Commonality analyses suggested some suppression effects between technique variables (Table 2).

Table 1. Female Javelin Throwers' Aerodynamic Distance Regression Equation

Variable	Mean	Coefficient	t (p)	Commonality%
Javelin inclination REL	41°	-0.284	-2.174 (0.039)	+5
Right elbow flexion RFD	23°	-0.108	-2.084 (0.047)	+5

Table 2. Male Javelin Throwers' Aerodynamic Distance Regression Equation

Variable	Mean	Coefficient	t (p)	Commonality %
Release angle	33°	-0.547	-2.595 (0.015)	-8
Right knee flexion LFD	140°	+0.261	+2.016 (0.053)	-8

DISCUSSION: Our data suggest that the primary factor for increasing aerodynamic distance is the alignment of the javelin, specifically the inclination of the javelin above the horizontal (inclination angle). In general the javelin should be inclined relatively low to minimise the angle of attack. Female javelin throwers achieve this by maintaining extension of their elbow through the crossovers up to the throwing procedure. Male javelin throwers achieve this by maintaining extension of their elbow throughout the throwing procedure, through greater adduction of their shoulder, and from a position where their right knee is extended at the block, which suggests a longer final stride and a less upright trunk position.
A lower javelin inclination tends to decrease the angle of attack by better matching the orientation of the javelin with the orientation of the release speed, since the angle of attack is the angle between them. Release angles tend to be low, because greater release speeds can be developed at lower release angles due to the structure and preferred line of action of the human body musculature. Reducing the inclination of the javelin instead of changing the orientation of the force applied to the javelin maintains great release speeds. Matching the inclination of the javelin to the release angle minimises the angle of attack. This is important for reducing the area of the javelin that is in contact with the air, which will reduce the drag force applied to the javelin and allow for improved flight and longer aerodynamic distances. It is especially important to reduce the angle of attack where the javelin is oriented above the line of action of the force, because this will reduce the drag force applied to the underside of the javelin. Drag force applied to the underside of the javelin, particularly at the back, would cause an increased overall drag, as well as a forward pitching motion and premature drop of the point of the javelin as pressure was applied behind the centre of mass of the javelin, which acts as the pivot point.

CONCLUSION: Aerodynamic distance is primarily determined by the alignment of the javelin at release. To increase aerodynamic distance javelin throwers should lower the inclination of the javelin to match their release angles and minimise the angle of attack.

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