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ASSOCIATIONS BETWEEN JAVELIN THROWING TECHNIQUE AND UPPER EXTREMITY KINETICS

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Javelin throwing requires great release speeds, necessitating javelin throwers to generate high forces. Their techniques exert significant musculoskeletal stress, which may cause injuries. The purpose of this study was to determine the associations between javelin throwing technique and upper extremity kinetics. Three-dimensional kinematic and kinetic data were reduced from video of javelin throwers competing in the USATF Championships. Correlations between elbow and shoulder kinetics and technique variables were calculated. High forces and torques were associated with the orientation of the javelin, shoulder horizontal adduction, and elbow flexion during the throw. These variables may be modified to reduce injury risk, however, they are also related to improved performance.

KEY WORDS: shoulder, elbow, force, torque.

INTRODUCTION: A javelin thrower makes complex, multi-joint movements that require great muscular strength, sophisticated coordination, and accurate control. These movements must develop the great forces that are necessary to accelerate the javelin to great release speeds, while carefully controlling the direction of the release (Best, Bartlett, & Morriss, 1993). As with other throwing motions, the generation of great forces exerts significant musculoskeletal stress on multiple joints of the upper extremity (Fleisig, Andrews, Dillman, & Escamilla, 1995). These stresses are the likely cause of acute and overuse injuries that lead to a loss of practice and competition time, may place a financial and quality of life burden on the javelin thrower, and may put the javelin thrower at an increased risk for secondary and degenerative injuries (Andrews & Fleisig, 1998).

Injuries sustained while javelin throwing may be preventable through training programs that modify technique to decrease musculoskeletal stress. There is a significant gap in the scientific and coaching literature of the mechanisms of javelin throwing injuries. Researchers, coaches, and trainers need to understand the relationships between javelin throwing technique and injury before they can design and evaluate injury prevention training programs. The purpose of this study, therefore, was to calculate the upper extremity kinetics of elite javelin throwers, and then to determine associations between javelin throwing technique variables and upper extremity kinetic variables.

METHODS: The longest legal trials by 40 right-handed female and 40 right-handed male javelin throwers competing in various meets from 2007 to 2010 were included in this study. Two high-definition digital video cameras were used to record all throws at a frequency of 59.94 frames per second. One of the cameras was placed behind and slightly to the left of the javelin runway, and the other camera was placed at the right side of the runway. A 24 point calibration frame that covered a volume 5 m long by 2 m wide by 2.5 m high was recorded before and after each competition, along with markers to establish a global reference frame. One trained and experienced researcher manually digitized 24 body and javelin landmarks to obtain two-dimensional coordinate data from the video clips. The Direct Linear Transformation procedure (Abdel-Azia & Karara, 1971) was used to obtain three-dimensional coordinate data from the digitized video clips.

The critical events of right foot down, left foot down, and release were used as time points at which to reduce key kinematic variables for comparison among athletes, and for calculating phase durations. Whole body speeds were calculated from the movement of the center of mass of the body. Release variables of the javelin were calculated using the center of mass of the javelin and the javelin reference frame as described by Best et al. (1993).

Shoulder joint angles were calculated as Euler angles of an upper arm reference frame relative to an upper trunk reference frame (Figure 1). Hip joint angles were calculated as Euler angles of a thigh reference frame relative to a lower trunk reference frame (Figure 1). Trunk rotation angles were calculated as Euler angles of the trunk reference frame relative to the global reference frame. Elbow joint angles, wrist joint angles, knee joint angles, and ankle joint angles were calculated as the angles between the longitudinal axes of the proximal and distal segments for those joints. Javelin orientations were calculated using the javelin reference frame described by Best et al. (1993).

The shoulder and elbow joint torques and forces were calculated using an inverse dynamic approach similar to the methods used by Feltner & Dapena (1986). The throwing arm was considered a four-link rigid segment model with frictionless pin-joints. The most distal link was the javelin, the link proximal to the javelin was the hand, the link proximal to the hand was the forearm, and the link proximal to the forearm was the upper arm. Cadaveric data were used to estimate the mass, centre of mass location, and moment of inertia of each body segment for every athlete (de Leva, 1996). The masses and centre of mass locations for the javelins were determined experimentally using the pendulum method (Alt, 1940). Joint forces and torques at the wrist, elbow, and shoulder were calculated in the global reference frame using an inverse dynamic procedure, and then transferred to the corresponding segment reference frames.

Pearson correlation analyses were performed to determine the relationships between the motions of the javelin, trunk, shoulder, elbow, wrist, hip, knee, and ankle, and peak right elbow varus torque, peak right shoulder internal rotation torque, peak right elbow joint resultant force, and peak right shoulder joint anterior shear force. A type I error rate of 0.05 was chosen to indicate statistical significance.

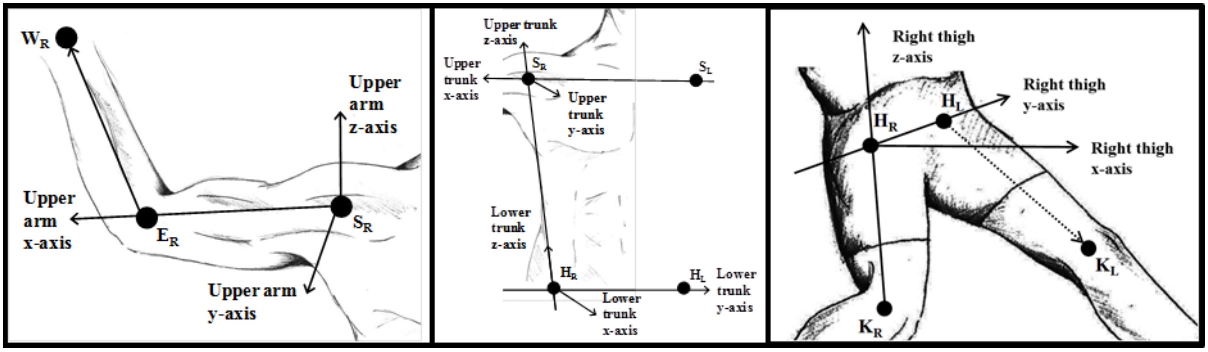

Figure 1: Shoulder and Hip Joint Angles

Reference frames for the upper arm, upper trunk, lower trunk, and thigh were established as displayed above. Shoulder joint angles were calculated as Euler angles of the upper arm reference frame relative to the upper trunk reference frame. Hip joint angles were calculated as Euler angles of the thigh reference frame relative to the lower trunk reference frame.

W_R = right wrist, **E_R** = right shoulder, **S_R** = right shoulder, **S_L** = left shoulder, **H_R** = right hip, **H_L** = left hip, **K_R** = right knee, **K_L** = left knee

RESULTS: The official distances ranged from 42.16 m to 66.67 m for females and from 60.61 m to 91.29 m for males. The mean release speeds were 23.0 ± 1.4 m/s for females and 27.2 ± 1.1 m/s for males. The mean release angles were 33° ± 3° for females and 34° ± 3° for males. The mean aerodynamic distances were 2.69 ± 3.70 m for females and 3.09 ± 4.06 m for males. The shoulder and elbow joint forces and torques were significantly correlated with: single support time, running speed at left foot down, javelin inclination angle at right foot down, javelin direction angle at left foot down and release, trunk tilt at left foot down, right shoulder horizontal adduction angle at right foot down, left foot down, and release, right shoulder external rotation angle at left foot down, and right elbow flexion angle at left foot down and release (Table 1).

These results were compared with previous studies that investigated the associations between technique variables and performance as measured by official distance.

Table 1: Shoulder and Elbow Force and Torque relationships: correlation coefficients for the bivariate correlations between the release and technique variables and the resultant shoulder and elbow internal joint forces and torques.

Release and Technique Variables	Shoulder Torque	Shoulder Force	Elbow Torque	Elbow Force
Single Support Time (seconds)	0.474	0.447		
COM Speed LFD (m/s)	0.520	0.546		
Javelin Inclination Angle RFD (°)	0.499	0.449	0.525	0.664
Javelin Direction Angle LFD (°)	0.531	0.690	0.616	0.438
Javelin Direction Angle REL (°)	0.461	0.606	0.514	0.563
Trunk Tilt LFD (°)		0.368		
R. Shoulder Horizontal Adduction RFD (°)			0.315	
R. Shoulder Horizontal Adduction LFD (°)	0.711	0.395	0.511	0.372
R. Shoulder Horizontal Adduction REL (°)	0.617	0.700	0.523	0.448
R. Shoulder External Rotation LFD (°)	0.739	0.640	0.702	0.468
R. Elbow Flexion LFD (°)	0.445	0.606	0.714	0.388
R. Elbow Flexion REL (°)			0.410	0.698

COM = Center of Mass, R. = Right, L. = Left, RFD = at Right Foot Down, LFD = at Left Foot Down, REL = at Release. All correlations are significant at the 0.05 level.

DISCUSSION: The purpose of this study was to calculate the upper extremity kinetics of elite javelin throwers, and then to determine associations between javelin throwing technique variables and upper extremity kinetic variables. Peak right elbow varus torques, right shoulder internal rotation torques, right elbow joint resultant forces, and right shoulder joint anterior shear forces were identified.

A great elbow varus torque is associated with increased stress of the UCL as this is one of the structures that acts to provide the torque necessary to resist the external valgus motion at the elbow during throwing movements (Andrews & Fleisig, 1998). A great elbow varus torque was found in all javelin throwing trials, and UCL rupture is a common injury in javelin throwing. A great elbow joint resultant force is related to bone fracture, particularly chipping of the elbow as the olecranon process impacts the olecranon fossa (Fleisig et al., 1995). A great elbow joint resultant force was found in all javelin throwing trials.

A great shoulder internal rotation torque is associated with tears to the rotator cuff, and shoulder impingement. Rotator cuff tears are likely to be a primary injury, where these small muscles actively stabilize the humeral head and resist external rotation during cocking. Impingement is likely to be a secondary injury arising from inflammation and debridement of rotator cuff and scapular muscles due to repetitive stress (Fleisig et al., 1995). A great shoulder internal rotation torque was found in all javelin throwing trials, and rotator cuff tears are common injuries in javelin throwing. A great shoulder joint anterior shear force is associated with shoulder dislocation and labrum injury, and may cause compression injuries to the head of the humerus or the rotator cuff muscles (Fleisig et al., 1995). A great shoulder joint anterior shear force was found in all javelin throwing trials, and labrum tears and dislocations are common injuries in javelin throwing.

Great torques and forces observed in a javelin thrower are not guaranteed to result in an injury. High forces in general are risk factors for fatigue and overuse injuries. An understanding of the torques and forces observed in javelin throwers is useful, however, because low forces and torques will probably not cause an acute injury to a javelin thrower.

Also, normative values of the forces and torques that occur in the shoulder and elbow joints of competitive throwing athletes may provide valuable information about the relative risks of joint forces and torques that cause injuries to body tissues.

Peak shoulder and elbow joint forces and torques were associated with increased running speed, single support time, inclination and orientation of the javelin, adduction of the shoulder, and flexion of the elbow. Concurrent research suggests that increased running speed, adduction of the shoulder, and flexion of the elbow are also associated with javelin throwing performance. This suggests that the motion of the throwing arm places significant stress on the joints of the throwing arm. Furthermore, any changes in these variables made to reduce injury risk may negatively impact performance. Strength training, altered training methods, altered training volume, and increased rehabilitation and treatment may be needed to reduce the risk for injuries without degrading performance. Increased single support time and javelin inclination are not associated with throwing performance. These variables may be modifiable to reduce the risk of injury without decreasing javelin throwing performance.

CONCLUSION: This study determined associations between shoulder and elbow kinetics and javelin throwing technique variables. Great shoulder and elbow forces and torques that may be associated with injuries are related to running speed, the orientation of the javelin during the throw, shoulder horizontal adduction, and elbow flexion. Many of these technique variables are also associated with improved technique. For the variables that are associated with great forces and torques only, injury prevention programs may target them for injury prevention training without affecting performance. To reduce injury risk without detrimenting performance, other approaches, such as flexibility or strength training, may be needed.

REFERENCES:

Abdel-Aziz, Y. I., & Karara, H. M. (1971). *Direct linear transformation from comparator coordinates into object space coordinates in close-range photogrammetry.* Paper presented at the ASP Symposium on Close Range Photogrammetry, Falls Church, VA.

Alt, R. L. (1940). A corrupted basic pendulum. *American Journal of Physics, 40(11),* 1688-1989.

Andrews, J. R., & Fleisig, G. S. (1998). Preventing throwing injuries. *Journal of Orthopaedic & Sports Physical Therapy, 27(3),* 187-188.

Best, R. J., Bartlett, R. M., & Morriss, C. J. (1993). A three-dimensional analysis of javelin throwing technique. *Journal of Sports Sciences, 11,* 315-328.

de Leva, P. (1996). Adjustments to Zatsiorsky-Seluyanov’s segment inertia parameters. *Journal of Biomechanics, 29(9),* 1223-1230.

Feltner, M., & Dapena, J. (1986). Dynamics of the shoulder and elbow joints of the throwing arm during a baseball pitch. *International Journal of Sport Biomechanics, 2(4),* 235-259.

Fleisig, G. S., Andrews, J. R., Dillman, C. J., & Escamilla, R. F. (1995). Kinetics of baseball pitching with implications about injury mechanisms. *American Journal of Sports Medicine, 23(2),* 233-239.

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