THREE-DIMENSIONAL COMPARISON OF SELECTED KINEMATICS BETWEEN MALE AND FEMALE INTERCOLLEGIATE JAVELIN THROWERS

G. Monique Butcher[1] and Jerry D. Wilkerson[2]
[1]Barry University, Miami Shores, Florida, USA
[2]Texas Woman's University, Denton, Texas, USA

The purpose of the study was to compare ROM, peak angular acceleration and percent throw values of peak angular acceleration of the upper arm, trunk, and pelvis segments, and elbow and knee joints between skilled male and female javelin throwers. Nine male and 11 female intercollegiate javelin throwers (n = 20) were videotaped using 2 120 Hz cameras. PEAK5 Motion Measurement System was used to analyze the data. Hotelling's T^2 tests revealed no significant differences ($p > .01$). However, females did appear to use the lower extremity differently by producing large amounts of pelvis ROM, pelvis peak angular acceleration, and knee extension peak angular accelerations. Both groups exhibited the proximal to distal sequencing of accelerations with the exception of upper arm internal rotation.

KEY WORDS: gender, kinematics, ROM, angular acceleration, percent throw, javelin

INTRODUCTION: While there is one optimal technique that will produce the greatest performance for a given javelin thrower (Best, Bartlett & Morriss, 1993), gender dynamics may influence which movement patterns become part of a thrower's technique (Fleisig, Barrentine, Escamilla & Andrews, 1996). Investigators have identified outcome and performance differences between males and females in javelin throwing (Komi & Mero, 1985; Rich, Gregor, Whiting, McCoy, & Ward, 1985). However, technique differences used by male and female throwers to produce those outcomes have been largely ignored. Other researchers have focused on release parameters such as release speed, angles associated with the javelin, and release height (Komi & Mero, 1985; Rich, Gregor, Whiting, McCoy & Ward, 1985). Results of studies that have examined segmental contributions to release parameters (Best, Bartlett & Morriss, 1993; Mero, Komi, Korjus, Navarro, & Gregor, 1994; Whiting, Gregor & Halushka, 1991) indicated that movement speed was generally advanced in an orderly progression from the proximal to distal segments. However, these studies involved primarily males. A complete understanding of this complex movement does not exist especially with regard to the specific movement patterns of female javelin throwers. In addition, acceleration patterns of javelin throwers have been minimally addressed. Therefore, the purpose of this study was to investigate the differences in the motor patterns used between skilled male and female javelin throwers. The dependent variables were total ROM, peak angular acceleration and percent throw value where the peak acceleration occurred in upper arm abduction, upper arm internal rotation, upper arm horizontal adduction, elbow joint extension, trunk lateral lean, pelvis rotation, and knee joint extension.

METHODS: Nine male and 11 female right-handed intercollegiate javelin throwers (n=20) were recruited for participation in this study from javelin throwers competing in the Texas Relays in April, 1997. Two stationary 120 Hz cameras were placed to the right side of the throwing area so that the angle between where the optical axes of the cameras intersect at the center of the control space was approximately 90^0. Both cameras were positioned 18 m from the throwing platform with the optical axis of the zoom lens oriented diagonally to the principle plane of motion. A control object (2 m x 2 m x 1.5 m) containing 25 points of known relative distance was videotaped for calibration. Three trials during competition were videotaped from which one legal trial was randomly chosen for analysis. PEAK5 motion measurement system was used to manually digitize the video records of each participant. Points digitized were the right shoulder, left shoulder, right elbow, right wrist, javelin grip, right anterior superior iliac spine (ASIS), left ASIS, right greater trochanter, right knee, and right ankle. The reliability of the primary investigator in manually digitizing was .99. Three-dimensional (3-D) coordinates were obtained using the Direct Linear Transformation Method (DLT) (Abdel-Aziz & Karara, 1971) and smoothed in the X, Y, and Z directions using a Butterworth 4^{th} Order Zero Lag digital filter.

Two adjacent points were used to define each segment. The knee and elbow angles were calculated by the software using the coordinates obtained for two segments with a common vertex. Flexion/Extension angles were derived by projecting the proximal and distal segments in the YZ (sagittal) plane. Trunk inclination was defined by projecting the trunk segment on the YZ plane. Lateral lean of the trunk was defined as that angle formed by the projection of the trunk segment onto the XY (frontal) plane. The projected segmental angle method was used to analyze pelvis rotation. The pelvis segment was projected onto the XZ (transverse) plane and angular movement was measured in relation to the X axis. Abduction/adduction was calculated as the angle formed by the projection of the upper arm segment on the XY plane. Horizontal abduction/adduction was calculated as the angle formed by the projection of the upper arm segment on the XZ plane. Since the internal/external rotation of the humerus about its long axis could not be directly measured, the rotation of the forearm about the upper arm's long axis was used, as similarly described by Feltner and Dapena (1986), and Rash and Shapiro (1995). Internal/external rotation was defined as the angle formed by the projection of the forearm segment on the XZ plane.

Total ROM values were calculated by examining the position data at the instant of left foot contact to the instant of release. Only ROM contributing in the direction of the throw was used for analysis. Peak angular acceleration values were selected as the highest magnitude of angular acceleration occurring from the instant of left foot contact to five frames after the instant of release. Percent throw value was defined as where the peak angular acceleration of the segments and joints occurred relative to the instant of release. The value was computed by mathematically dividing the temporal instant that the peak occurred by the temporal instant at release. Multiplying the number by 100 yielded a percent throw value. It was possible for a peak acceleration to occur after the instant of release. Therefore, five frames were digitized after release.

Multivariate Hotelling's T^2 tests were used to detect significant differences in the dependent variables between the genders. Alpha was set at .01 to control for the inflation of the family-wise Type I error rate.

RESULTS: Descriptive statistics for males and females are presented in Table 1. Table 2 depicts mean ROM values and standard deviations for each group. No significant differences in ROM between genders were observed ($t = 45.28$, $p = .0132$). Mean peak angular accelerations and standard deviations in overall order of magnitude are reported in Table 3. Results were not statistically significant ($t = 20.38$, $p = .1503$). Four elbow extension, two knee extension, and three shoulder internal rotation percent throw values were above 100% but within the five frame cut off. Mean percent throw values and standard deviations are reported in Table 4. Values are reported in ascending order of percent values to depict sequential timing. Results were not statistically significant ($t = 13.02$, $p = .3541$).

Table 1 Descriptive Data for Female and Male Javelin Throwers

	Females	Males
Age (yrs)	20.50 (1.28)	20.90 (1.90)
Height (m)	1.76 (4.60)	1.83 (6.22)
Weight (kg)	70.75 (7.98)	90.37(6.40)
Experience (yrs)	3.00 (1.84)	4.60 (1.01)
Total Throwing Time (s)	0.17 (0.02)	0.16 (0.02)
Distance (m)	41.45 (5.22)	63.56 (4.48)

Note. Mean values are presented followed by standard deviations in parentheses.

Table 2 Mean Range of Motion Values

	Females	Males
Elbow EXT	50.9 (13.2)	58.6 (25.6)
Knee EXT	12.8 (8.4)	8.5 (6.8)
Pelvis ROT	86.5 (14.9)	57.8 (16.1)
Shoulder HADD	79.1 (26.9)	91.6 (29.0)
Shoulder ABD	70.0 (14.9)	60.7 (16.9)
Shoulder IR	66.2 (12.7)	47.5 (24.6)
Trunk lean	16.8 (7.6)	14.5 (5.4)

Note. Values represent mean ROM in degrees and are followed by standard deviations in parentheses.

Table 3 Mean Peak Angular Acceleration Values

	Females	Males
Trunk lean	10.2 (11.6)	28.1 (45.1)
Knee EXT	23.9 (47.2)	7.3 (2.9)
Pelvis ROT	33.0 (72.1)	7.2 (3.8)
Shoulder IR	86.45 (61.5)	150.3 (225.3)
Shoulder ABD	113.7 (41.5)	136.6 (71.4)
Elbow EXT	128.0 (141.9)	176.8 (189.2)
Shoulder HADD	213.5 (122.8)	248.2 (224.9)

Note. Values represent mean peak angular acceleration (X 10^3) in deg\s^2 and are followed by standard deviations in parentheses.

Table 4 Mean Percent Throw Values

	Females	Males
Pelvis ROT	25.3 (13.9)	27.5 (27.0)
Trunk lean	45.4 (39.3)	49.3 (22.8)
Shoulder ABD	52.6 (15.0)	60.9 (17.6)
Knee EXT	66.7 (24.2)	68.1 (21.7)
Shoulder IR	80.0 (10.3)	87.4 (27.3)*
Shoulder HADD	82.0 (11.6)	70.2 (24.8)
Elbow EXT	89.8 (30.5)	78.1 (29.2)

Notes. Values represent mean percentages and are followed by standard deviations in parentheses. An * denotes that shoulder IR occurred last for the male group.

DISCUSSION: The major finding of this study is that while statistically male and female intercollegiate javelin throwers in this study produced similar kinematics at the elbow, shoulder, trunk, pelvis and knee, females showed evidence of using the extremities differently to achieve maximum implement displacement. As a possible adaptation of the female physique to the skill, females used larger amounts of pelvis ROM and produced greater acceleration peaks at the pelvis and knee. Males produced large amounts of ROM and angular acceleration in the shoulder and elbow, perhaps because of increased size and strength in the upper extremity compared to females. These results may also be linked to survey results by Butcher (1998) that indicated an increased incidence of lower extremity injuries in female collegiate javelin throwers, and an increased incidence of upper extremity injuries in males.

A second important finding of this study was the late occurrence of the internal rotation peak angular acceleration in all of the male throwers, and in 8 of the 11 females. Internal rotation is considered a primary generator of endpoint speed in non-javelin striking and throwing skills. It occurred late in the movement sequence, even after elbow extension in the males, which is in agreement with the findings of Elliot, Takahashi & Marshall (1996).

Proximal-to-distal sequencing does not appear to hold up when the analysis includes movement about all degrees of freedom.

The third noteworthy finding was that of the large amount of upper arm abduction ROM in relation to baseball pitching and football passing (Dillman, Fleisig & Andrews, 1993; Felter & Dapena, 1986; Rash & Shapiro, 1995). In most throwing and striking skills the abduction angle remains fairly constant. Higher and lower implement release points are generally achieved by leaning or tilting the trunk and not maneuvering the shoulder abduction angle with respect to the trunk. Interestingly, throwers in this study had relatively small trunk lateral lean angles. Perhaps upper arm abduction plays a greater role in determining release height and release position in javelin throwing than in other overarm throwing skills.

CONCLUSION: This study investigated kinematic differences in javelin throwing technique between skilled males and females. Results indicate that javelin throwing is a highly dynamic skill. Additionally, females may rely on the pelvis and lower extremity more than males to achieve horizontal displacement of the javelin. Thus, strength and conditioning programs that are specific to the sport demands and the athlete might aid in injury prevention and skill enhancement. Sports medicine specialists might use these results in developing a proper functional progression in injury rehabilitation. By being aware of the skill demands, injury evaluation techniques can also become more specific.

REFERENCES:

Abdel-Aziz, Y., & Karara, H. (1971). Direct linear transformation from comparator coordinates into object space coordinates in close-range photogrammetry. *ASP Symposium on Close Range Photogrammetry*, Falls Church, VA: American Society of Photogrammetry.

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.

Butcher, G. M. (1998). Injuries in intercollegiate javelin throwers: Suggestions regarding gender differences. *NATA Annual Meeting & Clinical Symposia,* Baltimore, MD: National Athletic Trainers' Association.

Elliot, B., Takahashi, K., & Marshall, R. (1996). Internal rotation of the upper arm: The missing link in the kinematic chain. In J. Abrantes (Eds.), *Proceedings of the XIV International Society of Biomechanics in Sports Symposium* (pp. 205-208). Lisboa, Portugal: Edicoes FMH.

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,* 235-259.

Fleisig, G. S., Barrentine, S. W., Escamilla, R. F., & Andrews, J. R. (1996). Biomechanics of overhand throwing with implications for injuries. *Sports Medicine, 21,(*6), 421-437.

Komi, P. V. & Mero, A. (1985). A. Biomechanical anlysis of Olympic javelin throwers. *International Journal of Sport Biomechanics,* 1, 139-150.

Mero, A., Komi, P., Korjus, T., Navarro, E., & Gregor, R. (1994). Body segment contributions to javelin throwing during final thrust phases. *Journal of Applied Biomechanics, 10,* 166-177.

Rash, G. S., & Shapiro, R. (1995). A three-dimensional dynamic analysis of the quarterback's throwing motion in american football. *Journal of Applied Biomechanics, 11,* 443-459.

Rich, R. G., Gregor, R. J., Whiting, W. C., McCoy, R. W., & Ward, P. (1985). Kinematic analysis of elite javelin throwers. In J. Terauds (Ed.), *Proceedings of the Second International Symposium of Biomechanics in Sports* (pp. 53-60). Del Mar, CA: Academic.

Whiting, W. C., Gregor, R. J., & Halushka, M. (1991). Body segment and release parameter contributions to new-rules javelin throwing. *International Journal of Sport Biomechanics, 7,* 111-124.