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COMPARISON OF TRUNK AND ARM MOVEMENT SEQUENCES OF JAVELIN THROWERS WITH SHORT AND LONG OFFICIAL DISTANCES

Hui Liu[1], Bing Yu[2]

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

The purpose of this study was to determine the effects of the sequences of initiations of trunk and upper extremity angular motions on the performance of javelin throwing. The sequences the initiations trunk and arm angular motions and maximum angular velocities were determined for 32 male and 30 female elite javelin throwers, and compared between groups with short and long official distances. Throwers with short and long official distances employed same sequences of trunk and arm angular motions. Male and female throwers employed different sequences of the trunk and arm angular motions. The sequence of the initiations of trunk and arm angular motions was different from that of the maximum trunk and arm angular velocities.

KEY WORDS: overhead throwing, biomechanics, kinematics.

INTRODUCTION: The sequences of trunk and arm segment and joint motions during the single support and delivery phases were believed to have a significant effect on javelin throwing performance. Literature repeatedly reported that elite javelin throwers showed an orderly progression in joint center maximum linear velocities from proximal to distal joints (Whiting, et al, 1991; Best, et al, 1993; Mero, et al, 1994; Bartlett, et al, 1996). Our previous study (Liu et al, 2010) found that initiations of lower and arm joint and segment angular motions of elite javelin throwers during the single support and delivery phases were not in a proximal-to-distal sequence. These results provided significant information for understanding the sequence of motions in overhead throwing events and technical training in javelin throwing.

The purpose of this study was to determine the effects of the sequence of initiations of trunk and arm angular motions and the sequence of maximum trunk and arm angular velocities on the performance in javelin throwing. We hypothesized that javelin thrower groups with short and long official distances employed different sequences to initiate their trunk and arm angular motions during the single support and delivery phases. We further hypothesized that javelin thrower groups with short and long official distances employed different sequences of maximum trunk and arm extremity angular velocities during the single support and delivery phases.

METHODS: The subjects of this study were 32 male and 30 female right handed elite javelin throwers who competed in the 2007 and 2008 USA Track and Field Outdoor National Championships. The trial with the longest official distance for each thrower was used in this study. Subjects in each gender were divided into a short official distance group (n = 16 for males, n = 15 for females) and a long official distance group (n = 16 for males, n = 15 for females). The cutoff official distance for the two groups was 70 m for male subjects and 50 m for female subjects.

Two high definition video camcorders were used to record the last cross step and the delivery stride of each subject at a frame rate of 60 frames/second. The angle between optical axes of the two cameras was approximately 95°. A calibration frame with 24 control points was used to calibrate camcorder positions and orientations. Real-life three-dimensional (3-D) coordinates of the 21 body landmarks and 3 marks on the javelin were estimated from the synchronized 2-D coordinates using the Direct Linear Transformation procedure (Abdel-Aziz and Karara, 1971). The raw real-life 3-D coordinates were filtered through a Butterworth low-pass digital filter at an estimated optimal cut-off frequency of 7.14 Hz (Yu and Andrews, 1998).

The lower trunk angles were calculated as the Euler angles of the lower trunk reference frame relative to the global reference frame and in an order of rotation of forward-backward tilt, left-right tilt, and left-right rotation. Shoulder joint angles were defined as the Euler angles of upper arm reference frame relative to an upper trunk reference frame. Lower trunk and shoulder angular velocities were calculated from Euler parameters (Haug, 1992). The upper trunk rotation angle was defined as the angle between the line connecting the left and right shoulder joints and the line connecting the left and right hip joints about the axis through the midpoints of the two lines (Leigh and Yu, 2007). The elbow and wrist angles were defined as the inclination angle between the longitudinal axes of the proximal and distal segments (Dun et al, 2008, Fleisig et al, 2009). The elbow, wrist, and upper trunk rotation angular velocities were calculated as the time derivatives of the corresponding angles.

The time of initiation of trunk forward and left tilts, upper trunk rotation relative to the lower trunk, shoulder abduction, horizontal abduction, and internal rotation, elbow extension, and wrist flexion motions were identified as described in a previous study (Liu et al, 2010). The time of the maximum angular velocity of a segment or joint angular motion was defined as the time when the maximum of the corresponding angular velocity occurred. The time of each of the selected trunk and upper extremity motions was normalized to the single support and delivery time.

Three-way ANOVAs with mixed design were also performed to compare normalized time of initiation of trunk and upper extremity angular motions and normalized time of maximum trunk and upper extremity angular velocities among motions, between groups, and between genders. A Type I error rate of 0.05 was chosen as the indication of the statistical significance.

RESULTS: Three-way ANOVA showed a significant interaction effect of motion and gender on the normalized time of initiation of trunk and upper extremity angular motions ($p = 0.023$). A two-way ANOVA was then performed to compare the normalized time of initiation of trunk and upper extremity angular motions among motions and between groups for each gender. Two-way ANOVAs showed no significant interaction effect of motion and group on the normalized time of the initiation of the trunk and upper extremity angular motions of male and female subjects($p = 0.904$, $p = 0.268$). Motion significantly affected the normalized time of the initiation of trunk and upper extremity angular motions for male and female subjects ($p < 0.001$) (Tables 1 and 2) while group did not ($p = 0.890$, $p = 0.755$).

Three-way ANOVA showed a significant interaction effect of motion and gender on the normalized time of maximum trunk and upper extremity angular velocities ($p = 0.029$). A two-way ANOVA was then performed to compare the normalized time of maximum trunk and upper extremity angular velocities among motions and between groups for each gender. Two-way ANOVAs showed no significant interaction effect of motion and group on the normalized time of maximum trunk and upper extremity velocities of male and female subjects ($p = 0.871$, $p = 0.825$). Motion significantly affected the normalized time of maximum trunk and upper extremity velocities of male and female subjects ($p < 0.001$) (Tables 3 and 4) while group did not ($p = 0.944$ for males, $p = 0.847$ for females).

DISCUSSION: The results of this study do not support our first hypothesis that the javelin thrower groups with short and long official distances employed different sequences to initiate the trunk and arm angular motions during the single support and delivery phases. The results of this study demonstrated that javelin throwers with short and long official distances level in each gender employed the same sequence to initiate trunk and upper extremity angular motions during the single support and delivery phases. The sequence of initiations of the trunk and arm angular motions was in an order of (1) upper trunk left rotation relative to lower trunk, (2) lower trunk left tilt, (3) lower Trunk forward tilt and right shoulder horizontal adduction, (4) right shoulder abduction, right elbow extension, and right shoulder internal rotation, and (5) right wrist flexion for male javelin throwers. This sequence was in an order of (1) upper trunk left rotation relative to lower trunk, (2) lower trunk left tilt, (3) lower Trunk forward tilt, (4) right shoulder abduction, (5) right shoulder horizontal adduction, right elbow extension, and right shoulder internal, and (6) right wrist flexion for female javelin throwers. These sequences were apparently not in a proximal-to-distal order.

The results of this study do not support our second hypothesis that javelin thrower groups with short and long official distances in a given gender employed different sequences of maximum trunk and upper extremity angular velocities during the single support and delivery phases. The results of this study demonstrated that javelin throwers in a given gender employed the same sequence of maximum trunk and upper extremity angular velocities. The sequence of maximum trunk and upper extremity angular velocities was in an order of (1) lower trunk forward tilt, (2) lower trunk left tilt, (3) upper trunk left rotation relative to lower trunk, (4) right shoulder internal rotation, right elbow extension, right shoulder abduction, and right shoulder horizontal adduction, and (5) right wrist flexion for male javelin throwers. This sequence was in an order of (1) lower trunk forward tilt, (2) lower trunk left tilt, (3) upper trunk left rotation relative to lower trunk, (4) right elbow extension, right shoulder abduction, and right shoulder internal rotation, and (5) right shoulder horizontal adduction and right wrist flexion for female javelin throwers.

CONCLUSION: The results of this study warrant the following conclusions: (1) javelin throwers with short and long official distances employed similar sequences of trunk and arm angular motions; (2) Male and female javelin throwers employed different sequences of the trunk and upper extremity motions; and (3) initiations trunk and arm angular motions and maximum trunk and arm angular velocities in javelin throwing follow different sequences. Improving javelin throwing performance may not need to modify sequences of trunk and arm motions

Table 1. Normalized time of initiations of trunk and arm angular motions (male).

Motions	Short Official Distance Group	Long Official Distance Group	P-value
Lower trunk forward tilt	0.68 ± 0.05	0.67 ± 0.07	
Lower trunk left tilt	0.77 ± 0.15	0.74 ± 0.10	0.001
Upper trunk left rotation	0.81 ± 0.09	0.85 ± 0.08	0.001
Shoulder internal rotation	0.92 ± 0.16	0.91 ± 0.17	0.001
Elbow extension	0.93 ± 0.04	0.90 ± 0.02	0.998
Shoulder abduction	0.92 ± 0.14	0.93 ± 0.15	0.282
Shoulder horizontal adduction	0.95 ± 0.08	0.96 ± 0.09	0.042
Wrist flexion	1.00 ± 0.03	1.01 ± 0.05	0.001

Table 2. Normalized time of initiations of trunk and arm angular motions (female).

Motions	Short Official Distance Group	Long Official Distance Group	P-value
Upper trunk left rotation	-0.07 ± 0.23	-0.21 ± 0.31	
Lower trunk left tilt	0.08 ± 0.18	0.03 ± 0.19	0.001
Lower trunk forward tilt	0.58 ± 0.11	0.60 ± 0.06	0.001
Shoulder abduction	0.70 ± 0.15	0.72 ± 0.12	0.001
Shoulder horizontal adduction	0.81 ± 0.05	0.83 ± 0.13	0.006
Elbow extension	0.81 ± 0.04	0.83 ± 0.04	0.998
Shoulder internal rotation	0.83 ± 0.05	0.83 ± 0.05	0.404
Wrist flexion	0.97 ± 0.03	0.97 ± 0.03	0.001

Table 3. Normalized time of maximum trunk and arm angular velocities (male).

Motions	Short Official Distance Group	Long Official Distance Group	P-value
Lower trunk forward tilt	0.68 ± 0.05	0.67 ± 0.07	
Lower trunk left tilt	0.77 ± 0.15	0.74 ± 0.10	0.001
Upper trunk left rotation	0.81 ± 0.09	0.85 ± 0.08	0.001
Shoulder internal rotation	0.92 ± 0.16	0.91 ± 0.17	0.001
Elbow extension	0.93 ± 0.04	0.90 ± 0.02	0.998
Shoulder abduction	0.92 ± 0.14	0.93 ± 0.15	0.282
Shoulder horizontal adduction	0.95 ± 0.08	0.96 ± 0.09	0.042
Wrist flexion	1.00 ± 0.03	1.01 ± 0.05	0.001

Table 4. Normalized time of maximum trunk and arm angular velocities (female).

Motions	Short Official Distance Group	Long Official Distance Group	P-value
Lower trunk forward tilt	0.65 ± 0.06	0.64 ± 0.05	
Lower trunk left tilt	0.78 ± 0.13	0.78 ± 0.16	0.001
Upper trunk left rotation	0.85 ± 0.06	0.85 ± 0.13	0.001
Elbow extension	0.90 ± 0.03	0.91 ± 0.02	0.798
Shoulder abduction	0.93 ±0.11	0.87 ±0.07	0.005
Shoulder internal rotation	0.96 ±0.13	0.92 ±0.14	0.360
Shoulder horizontal adduction	1.02 ± 0.10	0.97 ± 0.12	0.005
Wrist flexion	1.01 ± 0.06	1.02 ± 0.03	0.166

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