EFFECTS OF MOVEMENT SEQUENCE ON THE PERFORMANCE OF JAVELIN THROWING

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INTRODUCTION: The sequence of joint and segment movements during delivery phase is believed to significantly affect on the performance of javelin throwing. Literature reported that elite javelin throwers showed a proximal to distal sequence of joint center maximum linear velocities (Whiting et al., 1991; Best et al., 1993; Mero et al., 1994; Bartlett et al., 1996). The sequence of maximum joint center linear velocities, however, does not necessarily represent the sequence of joint or segment movements. The purpose of this study is to determine the effects of the sequence of upper extremity joint and segment angular movements on the performance of javelin throwing.

METHOD: 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 for this study. Subjects in each gender were divided into a high level group and a low level group based on their official distances. 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 fields/second and a shutter speed of 1/1000 seconds. Real-life three-dimensional coordinates of 21 body landmarks, the front edge of the grip, and the tail and tip of the javelin were obtained using the Direct Linear Transformation procedure. Raw coordinates were filtered through a low-pass digital filter at an estimated cutoff frequency of 7.14 Hz. The shoulder, elbow, and wrist joint angles, and the upper trunk rotation angle were reduced for analysis. The beginning times of 6 upper extremity joint and segment angular movements accelerating the javelin were identified and normalized to the double support time (time from left foot touchdown to release of the javelin).

Two-way ANOVAs with mixed design were performed for each gender to compare the sequence of the maximum linear velocity of the upper extremity joint centers and the sequences of the upper extremity joint and segment angular movements between levels of performance. A p-value of 0.05 was chosen as an indication of statistical significance.

RESULTS: The upper extremity maximum joint center linear velocities of male and female subjects were clearly in a proximal-to-distal sequence ($p < 0.001$, $p < 0.001$) (Table 1). Level did not affect this sequence for either gender ($p = 0.919$ for males, $p = 0.157$ for females). The normalized beginning times of upper extremity joint and segment angular movements of male subjects had significant sequential effects ($p < 0.001$), and were separated into 5 groups of movements (Table 2). Level did not have significant effects on the sequence of the upper extremity joint and segment angular movements of the male subjects ($p = 0.535$). The normalized beginning times of the upper extremity joint and segment angular movements of female subjects also had significant sequential effects ($p < 0.001$), and were separated into 4 groups of

movements (Table 2). Level did not have significant effects on the sequence of the upper extremity joint and segment angular movements of female subjects ($p = 0.210$).

Table 1. Sequence of maximum joint center linear velocities of elite javelin throwers (% double support time) (Mean ± SD).

Joint Centers	Male		Female	
	Low level	High level	Low level	High level
Hip	0.34 ± 0.13	0.29 ±0.17	0.47 ±0.07	0.47 ±0.09
Shoulder	0.73 ± 0.08	0.73 ±0.07	0.73 ±0.07	0.70 ±0.07
Elbow	0.83 ± 0.03	0.81 ±0.04	0.82 ±0.03	0.82 ±0.03
Wrist	0.95 ± 0.04	0.93 ±0.04	0.92 ±0.02	0.94 ±0.03

Table 2. Sequence of upper extremity movements (% double support time) (Mean ± SD).

Male			Female		
Movement	Low level	High level	Movement	Low level	High level
Upper trunk forward rotation	-0.14 ±0.34	-0.15 ± 0.33	Upper trunk forward rotation	-0.07 ±0.23	-0.21 ±0.31
Shoulder horizontal adduction	0.70 ± 0.09	0.67 ± 0.10	Shoulder abduction	0.70 ± 0.15	0.72 ±0.12
Shoulder abduction	0.80 ± 0.05	0.76 ± 0.10	Shoulder horizontal adduction	0.81 ± 0.05	0.74 ±0.13
Elbow extension	0.83 ± 0.04	0.82 ± 0.04	Elbow extension	0.81 ± 0.04	0.83 ±0.04
Shoulder internal rotation	0.85 ± 0.05	0.86 ± 0.04	Shoulder internal rotation	0.83 ± 0.05	0.83 ±0.05
Wrist flexion	0.97 ± 0.03	0.97 ± 0.03	Wrist flexion	0.97 ± 0.03	0.97 ±0.03

DISCUSSION: The results demonstrated that the sequence of the maximum joint center linear velocities does not represent the sequence of the lower and upper extremity joint and segment angular movements. The results of this study showed that the maximum joint center linear velocities of javelin throwers were in a proximal-to-distal sequence while the beginning times of the upper extremity joint and segment angular motions were not in such a sequence. The results of this study also showed that the shoulder angular movements did not start at the same time, and that some shoulder joint angular movements started at the same time with elbow extension. Male and female throwers apparently used different sequences of upper extremity joint and segment angular movements. These results suggest that the upper extremity joint and segment angular movements in javelin throwing is not in a simple proximal-to-distal sequence.

Neither the sequence of the maximum joint center linear velocities nor the sequence of the beginning of the joint and segment angular movements appears to be a factor affecting the performance of javelin throwing in this study. The performances of the high and low level groups in each gender were significantly different, while the sequences of the appearances of the maximum joint linear velocities and the upper extremity joint and segment angular movements were not. Further, the variations in the sequences of the upper extremity joint and segment angular movements of the two groups in each gender were similar. These results suggest that the difference in performance between the high and low level groups in this study was due to other factors instead of the sequence of the upper extremity joint and segment angular movements.

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