UPPER EXTREMITY ANALYSES OF STANDING THROW WITH THREE WEIGHTS OF SHOT PUT

Hsiente Peng, Chenfu Huang and Hsiensheng Peng*

Institute of Physical Education, National Taiwan Normal University, Taipei, Taiwan

*** Institute of Physical Education, National Taipei University of Education, Taipei, Taiwan**

The purpose of this study was to analyse kinematic valuables of the throwing extremity with three weights of shot put. Three-dimensional method was used to analyze the upper extremity of shot putters performing standing throws. Nonparametric statistical test of Friedman two-way analysis of variance by ranks was conducted for the valuables (p=.05). There were significant differences between 8 lb. and 16 lb. shot put in the measure distance, release velocity and maximal angular momentum of the forearm. The proximal-to-distal sequencing was found in terms of segment angular momentum.

KEY WORDS: shot put, throw, upper extremity, proximal-to-distal sequencing.

INTRODUCTION: The execution of throwing is a complex multi-segment motion which is concerning the relationship between joints and segments. Throwing sports such as baseball, handball, rugby, javelin, discus, shot put etc. are generally regarded as whip-lash movements of the throwing arm. Among them, shot put is the heaviest instrument whose throwing pattern is very different from the others. Studies concerning upper extremities of throwing sports were mostly in light instruments (Bartlett, Muller, Lindinger, Brunner & Morriss, 1996; Fleisig, Escamilla, Andrews, Matsuo, Satterwhite & Barrentine, 1996; Joris, Edwards van Muyen, van Ingen Schenau & Kemper, 1985). A few were in heavy instruments. Therefore, we selected shot put as our study subject and concentrated on the throwing arm. The purpose of this study was to analyse kinematic valuables of the throwing extremity with three weights of shot put.

METHOD: Seven male collegial shot putters (age: 20±3 years; height: 178±9 cm; weight: 10±24 kg) served as subjects to perform standing throws with three weights of shot put (8, 12 and 16 lb.). The definition of the standing throw: shot putters stood with the back toward the direction of throw, stepped back with the left foot, and then rotated the hip following by the chest and throwing arm. Each subject performed at least two throws without fouls. The best trial with the farthest measured distance for each subject was analyzed. Two Redlake high-speed cameras (sampling rate: 125Hz; Motion Scope, San Diego, CA) were synchronized to record the three dimensional motion of the shot put. One was in the side of the circle and the other was in the back of the circle. A Peak 3D calibration frame with 25 control points was used to calibrate the locations and orientations. Those images were digitized by KWON 3D motion analysis system. The raw data was smoothed by a fourth-order Butterworth low-pass filter with 6Hz cut-off frequency. Nonparametric statistical test of Friedman two-way analysis of variance by ranks was conducted for the valuables (p=.05). In the 3D analysis, joint-angles (non-projected angles) were defined from joint-points shown in figure 2.

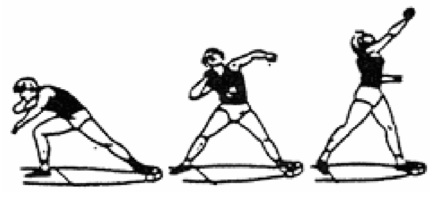

Figure 1: Standing throw of shot put

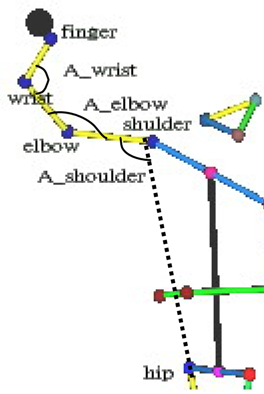

Figure 2: Joint-angles. (non-projected angles)

RESULTS AND DISCUSSION:

Table 1: Measured distance, throwing time and velocity, angle and height at release.

	8 lb.	**12 lb.**	**16 lb.**
Measured Distance (m)	15.58±1.97 [c]	13.87±2.27	11.57±2.42 [a]
Throwing time (msec)	523±21	527±33	607±153
Release Velocity (m/sec)	11.69±0.95 [c]	10.88±3.89	9.68±0.13 [a]
Release Angle (deg)	38.62±1.12	38.39±3.08	38.79±0.11
Release Height (m)	2.11±1.06	2.09±2.03	2.08±0.11

[a] significant difference to 8 lb. shot; [c] significant difference to 16 lb. shot

Table 2: Angle, angular velocity and acceleration of shoulder, elbow and wrist at release

		8 lb.	12 lb.	16 lb.
Shoulder	Anglular distance* (deg)	129.8±12.5	128.4±16.2	125.4±13.7
	Angular velocity (deg/sec)	428.7±69.4	423.8±110.9	371.6±233.2
	Angular acceleration (deg/sec^2)	-11257.3±7521.1	-11198.3±4315.6	-6216.0±3756.0
elbow	Anglular distance (deg)	161.6±3.8	163.7±8.2	161.2±7.3
	Angular velocity (deg/sec)	598.2±149.0	545.7±120.2	439. 7±310.8
	Angular acceleration (deg/sec^2)	-24222.2±9909.2	-24353.7±6794.1	-18118.4±6065.8
wrist	Anglular distance (deg)	149.2±11.8	149.7±3.4	143.6±11.0
	Angular velocity (deg/sec)	558.8±241.1	578.8±185.2	599.2±463.5
	Angular acceleration (deg/sec^2)	-19562.5±17212.9	-20509.2±18672.1	-12875.6±11357.3

* angular distances are non-projected angles.

Table 3: Maximal angular momentum and time before release

		8 lb.	12 lb.	16 lb.
Upper arm	Maximal angular momentum (kg · m^2/sec）	5.30±1.80	5.33±2.08	5.00±1.95
	Reaching-time before release (msec)	47±9	45±10	54±32
Fore arm	Maximal angular momentum (kg · m2/sec）	7.46±2.24 [c]	7.44±2.48	6.51±1.79 [a]
	Reaching-time before release (msec)	16±17	16±19	7±13
Hand	Maximal angular momentum (kg · m2/sec）	3.22±0.94	3.11±0.89	2.99±0.88
	Reaching-time before release (msec)	1±3	1±3	0±0

[a] significant difference to 8 lb. shot; [c] significant difference to 16 lb. shot.

In practice, throwing a lighter shot put, shot putter would get a longer measured distance and greater release velocity. In this study, they also got shorter throwing time and greater release height. Significant differences were found between 8 lb. and 16 lb. shot put in measured distance and release velocity. Having different power, shot putters would adjust their release angle in order to get maximal release velocity, and elite shot putters would maintain their release angle from a maximum range. (Linthorne, 2001) In this study, no matter what weights shot putters threw, they kept release angle in the range of 38 to 39 degree (Table 1.). With the weight of shot put increasing, the angle, angular velocity and acceleration of shoulder

and the angular velocity of elbow decrease. Nevertheless the angular velocity of wrist increases with the weight of shot put increasing. The angular acceleration of shoulder, elbow and wrist at release is negative. It means the movements of shoulder, elbow and wrist are for deceleration at the moment. (Table 2.)
Table 3 lists maximal angular momentum and time before release. The maximal angular momenta about the upper body center of mass of the forearm and hand decrease with the weight of shot put increasing, furthermore, there is a significant difference between 8 lb. and 16 lb. shot put in maximal angular momentum of the forearm. Moreover, the time of their maximal momenta are very close to the shot put release. That of hand's maximal momentum is nearly at the shot put release. The output sequence of the maximal momentum is the following – upperarm → forearm → hand. Figure 3 shows the proximal-to-distal sequencing in terms of segment angular momentum.

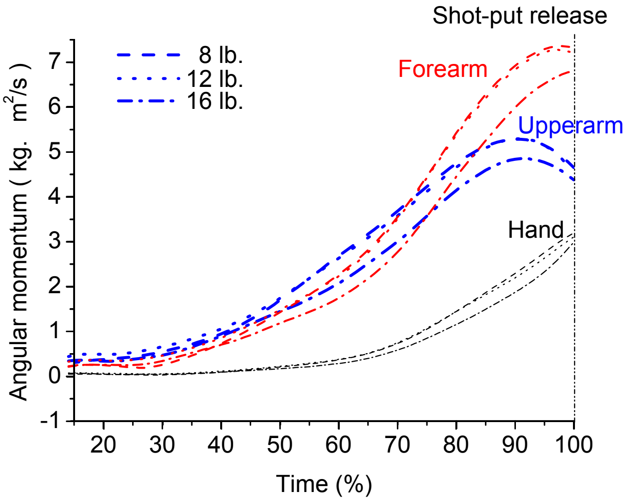

Figure 3: Angular momenta of shoulder, elbow and wrist with 8, 12 and 16 lb. shot put.

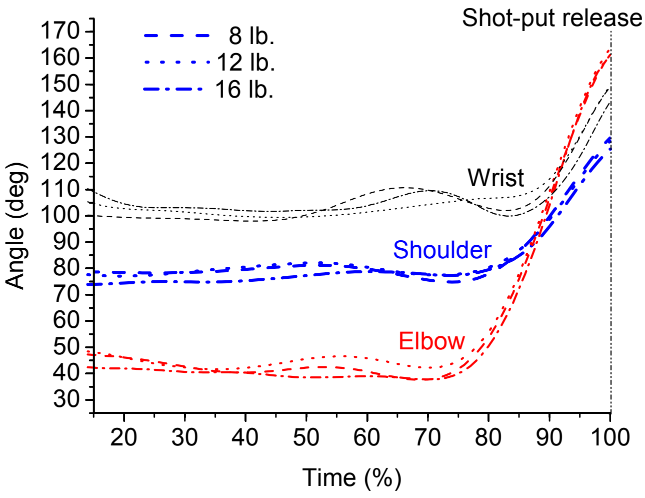

Figure 4: Angles of shoulder, elbow and wrist with 8, 12 and 16 lb. shot put.

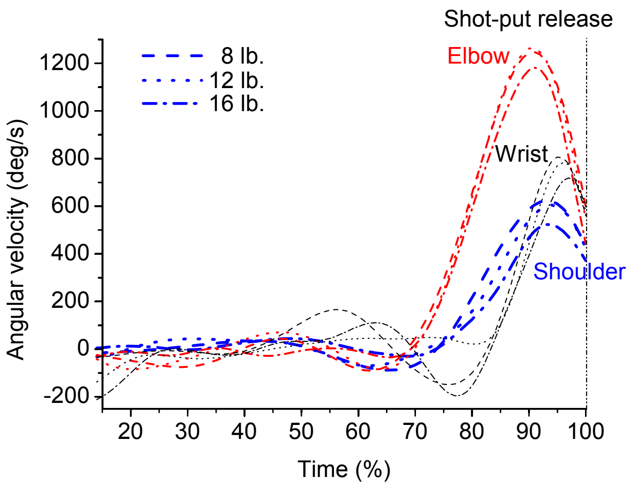

Figure 5: Angular velocity of shoulder, elbow and wrist with 8, 12 and 16 lb. shot put.

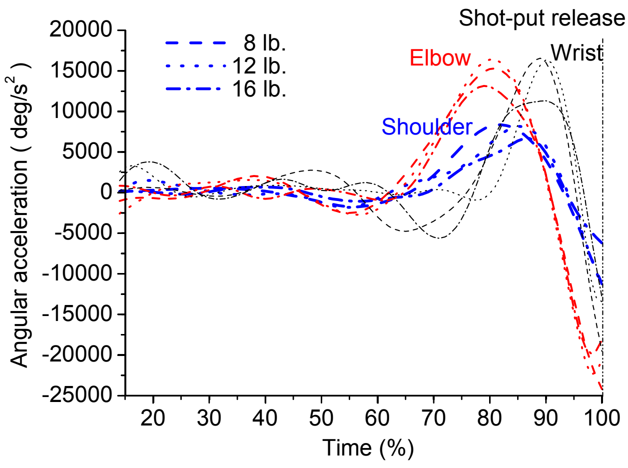

Figure 6: Angular acceleration of shoulder, elbow and wrist with 8, 12 and 16 lb. shot put.

Figure 4 shows the angles of shoulder, elbow and wrist during the shot put throws. Before shot putters stretched their muscle to thrust, the wrist angle is greater than the shoulder and elbow angle. At thrusting, the elbow has the greatest range of motion. In addition, the elbow extends first following by the shoulder and then the wrist. At release, the elbow angle is the greatest and the shoulder angle is the smallest. Figure 5 shows that the maximal angular velocity of elbow is greater than that of the wrist and the shoulder. The sequence of the maximal angular velocity is the following – elbow → shoulder → wrist. It is also found in the maximal angular acceleration (Figure 6.) and in the start of extension of joint-angle at thrusting. (Figure 4.) The throwing arm does not show the proximal-to-distal sequencing in terms of joint angular velocity and acceleration. Putnam (1993) indicated that resultant linear velocities of segment endpoints clearly show that the distal ends of segments progressively get faster in a proximal-to-distal fashion, however, descriptions of sequential segment motions in terms of resultant endpoint velocities have a limited value. He also indicated that segment angular velocity data provide a clear description of proximal-to-distal sequencing. In this study, segment angular momentum was calculated by both of linear velocity of segment center of mass and segment angular velocity. Putnam (1993) mentioned that factors affecting the timing of segment motions are directly related to the way segments interact. These include the lengths, masses, mass centre locations and moments of inertia of the segments. We supposed that the outcome-distinction among angular momentum, joint angular velocity and acceleration was that the angular momentum included the aforementioned factors. In addition, Figure 5 and 6 show that both the angular velocity and acceleration of the shoulder have the smallest peak values comparing to the other two joints before shot put release.

CONCLUSION: The analysis of the standing throw with three weights of shot put gave us information in the heavy-instrument throwing. There were significant differences between 8 lb. and 16 lb. shot put in the measure distance, release velocity and maximal angular momentum of the forearm. The throwing pattern with three shot put weights in this study was generally similar. It is good strategy for coaches to teach shot put throwing or for shot putters to practice from light to heavy one. The merits are shortening throwing time and speeding up segment motions for shot putters to experience the speed-power of shot put. This study shows the proximal-to-distal sequencing in terms of segment angular momentum. We supposed that comprehensive considerations could explain human movement more accurately. In order to make deeper descriptions and explanations of the interactive movements of the throwing arm, the joint moment or electromyography would be needed.

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Acknowledgement

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