MOMENT AND POWER OF SHOULDER AND ELBOW IN SHOT-PUTTING

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The purpose of this study was to quantify the moments and power of the elbow and shoulder joints. Three-dimensional methods and inverse dynamics were used to analyze the throwing arm of shot putter performing standing throws. The proximal to distal sequence was found on moments and power of the elbow and shoulder. The mechanical outputs from elbow and shoulder muscles were mainly energy generation.

KEY WORDS: shot put, throw, inverse dynamics, proximal to distal sequence.

INTRODUCTION:

Throwing is a multi-segmented motion involving interaction between the shoulder and elbow joints of the upper extremity.. To quantify this interaction, researchers have often analyzed the joint kinetics (Feltner, 1989; Feltner & Dapena, 1986; Fleisig, Andrews, Dillman, Satterwhite & Escamilla, 1995; Fleisig, Escamilla, Andrews, Matsuo, Satterwhite & Barrentine, 1996; Escamilla, Fleisig, Barrentine, Andrews & Moorman, 2002; Joris, Edwards Van Muyen, Van Ingen Schenar & Kemper, 1985). The joint moment reflects the net muscular activation at the joint where ligaments, bones, and other passive structures may also contribute (Andrews, 1982). The ability to generate peak power is crucial for optimal performance in many sports. Many of the previous investigations of throwing sports have assessed the intersegmental motions, moments and powers of baseball pitching (Feltner, 1989; Feltner et.al., 1986; Fleisig et.al., 1995; Fleisig et.al., 1996; Escamilla et.al., 2002). The motion of shot putting is very different where shot putters hold the shot on their necks in the beginning and then throw it using a putting motion due to the weight of the shot. No study shows the quantitative information on the joint kinetics during such heavy weight throwing sports. The purpose of this study was to quantify the moments and power of the elbow and shoulder joints in shot putting.

METHODS:

Seven male collegial shot putters (age: 20±3 years; height: 178±9 cm; weight: 100±24 kg.) volunteered to be the subjects in this study. Each subject provided their informed consent prior to participation. The protocol was approved by the Taipei Medical University Ethical Committee. All subjects had no injury during the time of the study and were right-handed throwers. 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 trail with the farthest measured distance for each subject was analyzed.

Three dimensional kinematical data were obtained at sampling rate of 125Hz from two synchronized Redlake high-speed cameras (Motion Scope, San Diego, CA, USA.). The video capture volume was approximately 3.0m x 3.0m x 3.0m and centered in the circle. A 25-points calibration frame (Peak Performance Technologies, Inc., Centennial, CO, USA.) was used at the beginning and the end of the data collection session. The collected motion data was calibrated with Direct Linear Transformation (DLT) procedures and analyzed in Kwon 3D motion analysis system (Visol Inc., Seoul, Korea) . All digital coordinate data was smoothed with a Butterworth fourth-order, zero-lag, low-pass filter at 6Hz cut-off frequency (Winter, 1990).

The body was modeled as four segments which were trunk, upperarm, forearm, and hand. Markers were digitized manually at hip, shoulder, elbow, wrist joints, middle finger landmarks, and center of shot put. Segment inertia parameters were obtained from the model set in Kwon 3D motion analysis system (Kwon, 1993, 1996, 2001). The following definitions were used in the local reference frames at joints. Mid-hip was defined as the midpoint of a line segment between the two hip markers, and mid-shoulder was defined as the midpoint of a line segment between the two shoulder markers. Trunk vector was a unit vector from the mid-hip to the mid-shoulder. Two reference frames were defined in this study (Table 2). Inverse dynamics was used to caculate the moments and power at joints (Feltner et. al., 1989; Fleisig et. al., 1995). Moreover, there was a external force exerted by shot put (7.26 kg.) which was caculated with a foumula *F=ma* where *m* was the shot put mass and *a* was the shot put accleration. The reaction force of shot put acting at the hand was taken account into the inverse dynamics calculations.

Table 1: Local reference frames

Reference Frame	Unit vector	Definition	Description
Shoulder Reference Frame (R_s)	X_s	From right shoulder to right elbow	Distal direction of upper arm
	Y_s	Cross product of trunk vector and X_s	Anterior direction of shoulder
	Z_s	Cross product of X_s and Y_s	Superior direction of shoulder
Elbow Reference Frame (R_e)	X_e	From right elbow to right wrist	Distal direction of forearm
	Y_e	Cross product of X_e and $-X_s$	Medial direction of elbow
	Z_e	Cross product of X_e and Y_e	Anterior direction of elbow

RESULTS:

The throwing phase in the study was from the shot put off the neck to the shot put release from the hand. This study did not account for the reaction force of the neck when shot putter held the shot put on his neck. The group mean±SD for measured distance, release velocity, angle, height, and the time-duration of the throwing phase were 11.57±2.42 m, 9.68±0.13 m/sec, 38.79±0.11 deg, 2.08±0.11 m, and 161.1±42.7 ms, respectively.

The moment and power patterns generated about the elbow and shoulder during the throwing were shown in Figure 1 and 2. The presented curves were the means and SDs of the subjects. The throwing time was normalized to 100% from the shot put off the neck to the shot put release. Due to the limitations of the experimental setup, digitization and joint degrees of freedom, the joint moments about the X_s, X_e and Z_e were disregarded in this study. In the beginning of the throwing motion, the elbow generated a flexion moment. The elbow flexion moment changed to extension moment around 60~70% normalized time. The peak extension moment was reached around release. The elbow exhibited power absorption in the beginning and then changed to power generation around 30~40% normalized time. The elbow peak power generation occured around release.

The shoulder showed horizontal adduction and abduction moment patterns during shot putting. The horizontal adduction moment was relatively greater than the abduction moment. Their peak moments occurred around 60~70% normalized time. The shoulder showed power absorption in the beginning and then shortly changed to power generation around 10~20% normalized time. The peak shoulder power generation was reached around 60% normalized time. Morever, the peak power generation of shoulder was greater than that of elbow.

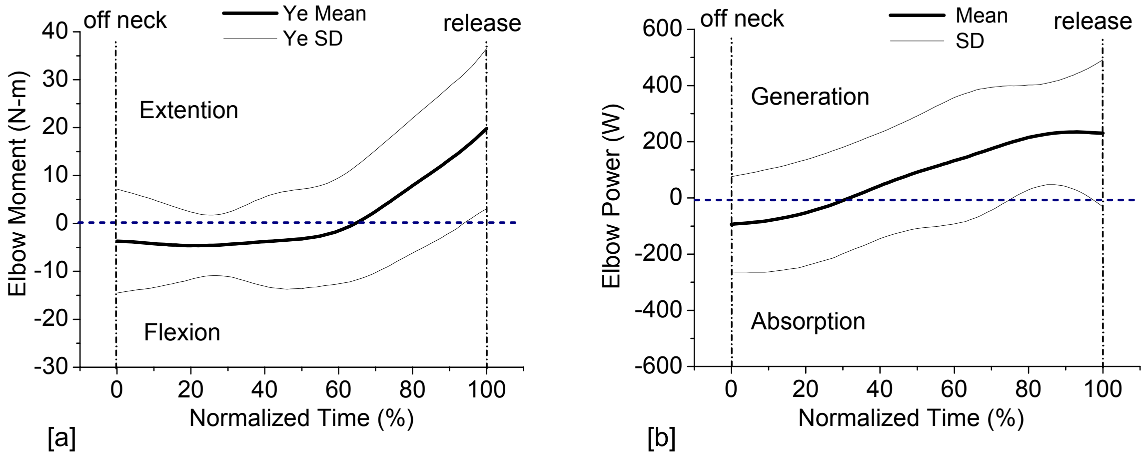

Figure 1: Elbow joint [a] Moment; [b] Power

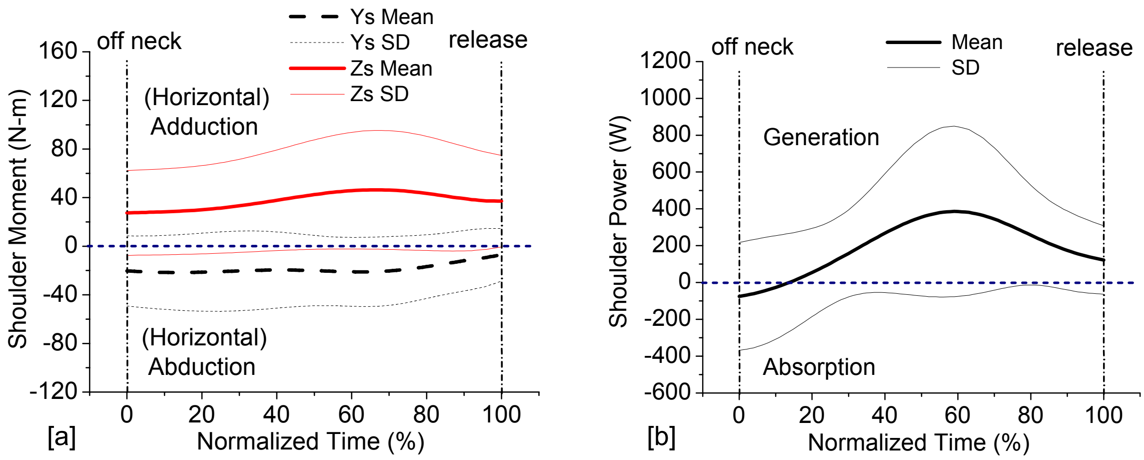

Figure 2: Shoulder joint [a] Moment; [b] Power

DISCUSSION:

The increase of net extension moment may be due to increases in the activity of extensors or decreases in activity of flexors. Due to the indeterminancy problem and the lack of information about muscle activities, we could only interpret the net moments and power in a restrictive way (Jacobs & Ingen Schenau, 1992). However, the moment of force patterns showed how the shot putter responded to the forces acting during shot putting. In this study, we found that the relative timing of shoulder peak moments and power generation were very close to the transition between the elbow flexor to extensor moment. Moreover, the elbow extention moment and power generation reached their peak. This demonstrated some sequencing of joint kinetics. The power at each joint was calculated using the formula $P=Mj \cdot \omega j$ where *Mj* was the net moment of force at joint *j* and ωj was the joint angular velocity (Winter, 1983). Joint angular velocity data provides a clear description of proximal to distal sequencing of joint movements (Putnam, 1993). Thus, it is logical that the shoulder and elbow joint moments and powers showed proximal to distal sequence in this study. Furthermore, for the intersegmental moments to play a part in the more distal segments' acceleration, the muscle group must apply force to it (Kreighbaum & Barthels, 1985). In terms of muscle function in shot putting, the shoulder muscular efforts contributed to the upperarm acceleration and the elbow muscular efforts contributed to the forearm acceleration in sequencing.

The elbow showed a large extention moment and the shoulder showed primarily patterns of horizontal adduction and abduction moment during the throwing. The arm motions of shot putting were elbow extension and shoulder horizontal adduction and abduction corresponding to the joint moment patterns. Moreover, the functional significance of the joint moment patterns in terms of energy generation and absorption can best be understood by examining the power (Winter, 1983). Both elbow and shoulder joint muscles large amounts of power generation during the shotput.

CONCLUSION:

The quantitative moments and power pattern in shot putting displayed proximal to distal sequencing from shoulder to elbow. The mechanical output from elbow and shoulder muscles were mainly power generation during this kind of explosive throwing sport except at the beginning. The shoulder muscles exerted more power generation than the elbow muscles in shot putting.

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