# DYNAMICS OF THE SHOULDER AND ELBOW JOINTS OF THE THROWING ARM DURING ROTATIONAL SHOT PUTTING - CASE STUDY

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The purpose of this study was to clarify the dynamical interacting characteristics between the segments of the shot put throwing arm, and to compare the quantitative information between a beginner and an experienced rotational shot putter. The DLT method of 3D cinematography was used. In the throwing motion, compressive force and horizontal adduction torque were mainly exerted at the shoulder joint, while anterior force and flexion torque were mainly exerted at the elbow joint, i.e. the muscle efforts mainly contributed to those forces and torques aforementioned. Subjects' patterns of forces and torques were generally similar, but we found that the timing of anterior, superior forces, external rotation torque, and distractive force were markedly different.

**KEY WORDS:** rotational shot put technique, throwing, inverse dynamics.

**INTRODUCTION:** Feltner & Dapena (1989) stated that a model using an inverse dynamics approach to compute the net joint forces and torques exerted on a segment by the segments adjacent to it could link the motion with the kinetic factors responsible for it and the muscular activities at its articulations. Andrews (1982) stated that the generally applicable indirect method for discovering the relationship that exists between resultant joint torques and muscular activity is the use of model studies and temporal EMG data. Many researchers studied the kinetics of baseball throwing arm with the model method (Feltner, & Dapena, 1986; Feltner, & Dapena, 1989; Fleisig, Escamilla, Andrews, Matsuo, Satterwhite, & Barrentine, 1996). Shot put throwing arm is crucial for the performance. Discovering the muscular activities of the shot put throwing arm could be helpful for its specific training. However, there was no study on the kinetics of the shot put throwing arm. The purpose of this study was to clarify the dynamical interacting characteristics between the segments of the shot put throwing arm, and to compare the quantitative information between a beginner and an experienced rotational shot putter.

**METHODS:** Two male right-handed collegiate shot-putters served as subjects for this study. Subject1 (S1) is a beginner and practiced the rotational technique only for one month. Subject2 (S2) is an experienced shot-putter who has practiced the skill for four years. Four trials were collected for each subject, and the best performance was selected to analyze. The subjects' characteristics and performances were shown in Table 1. The DLT method of 3D cinematography was used. Two Redlake high-speed digital cameras (125Hz) 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 and the build-in human body parameters were used. The raw data was smoothed by a fourth-order Butterworth low-pass filter with 6Hz cut-off frequency.

**Table 1 Characteristics and Performances.**

| | S1 | S2 |
|---|---|---|
| Height (cm) | 170 | 176 |
| Mass (kg) | 86 | 126 |
| Age (yrs) | 18 | 22 |
| Distance (m) | 13.17 | 15.64 |
| Release Velocity (m/s) | 11.03 | 12.18 |
| Release Angle (degree) | 35.62 | 31.06 |
| Release Height (m) | 1.90 | 1.98 |

To aid in constructing local reference frames, some definitions were made. 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 made in the study (Figure 1 and Table 2). R s and R e was defined to aid interpreting the force and torque applied by the upper arm to the forearm about the elbow, and the force and torque applied by the trunk to the upper arm at the shoulder, respectively. The force and torque were separated into orthogonal components using the axes shown in Figure 1 and Table 2. The anatomically relevant meaning of the force and torque were shown in Table 3 (Feltner et. al., 1989; Fleisig et. al., 1996). The mass of the shot was set equal to 7.26kg. To simplify interpretation of these data, the rotational shot put motion was divided into four phases by five events (Figure 2).In order to compare to S1 with S2, those data were normalized. Temporal value was a percentage of the throwing completed (measured from RFO to SPO), where 0% corresponded to RFO and 100% corresponded to SPO. Forces were normalized by percent body weight (unit: N) (% BW), while torques were by percent body weight times body height (unit: m) (% BW-BH) (Escamilla, Fleisig, Barrentine, Andrews, & Moorman, 2002).

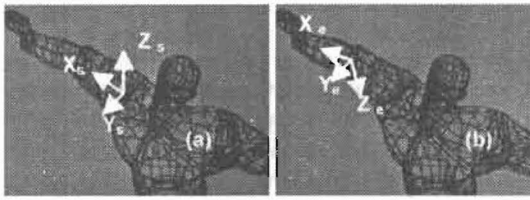


Figure 1: Local reference frames (a) $R_s$ (b) $R_e$.

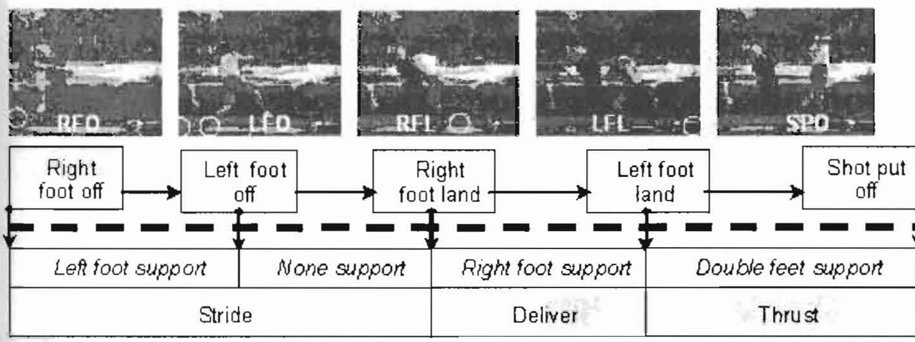


Figure 2: Events & Phases.

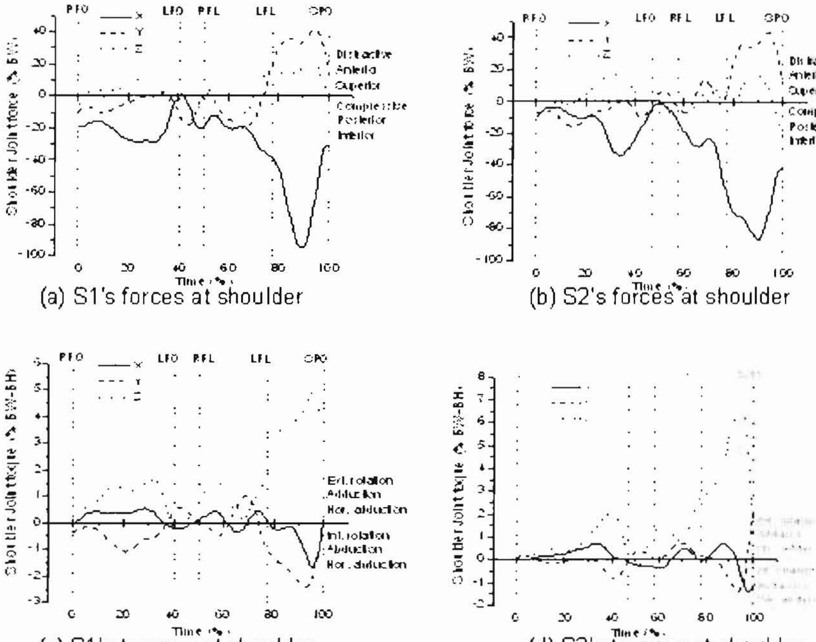
**Table 2 Local reference frames.**

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

**Table 3 The anatomically relevant meaning of the force and torque.**

| Vector of $R_s$ | Shoulder Force | Shoulder Torque | Vector of $R_e$ | Elbow Force | Elbow Torque |
|---|---|---|---|---|---|
| $+X_s$ | Distractive | External rotation | $+X_e$ | Distractive | Supination |
| $-X_s$ | Compressive | Internal rotation | $-X_e$ | Compressive | Pronation |
| $+Y_s$ | Anterior | Adduction | $+Y_e$ | Medial | Extension |
| $-Y_s$ | Posterior | Abduction | $-Y_e$ | Lateral | Flexion |
| $+Z_s$ | Superior | Horizontal adduction | $+Z_e$ | Anterior | Varus |
| $-Z_s$ | Inferior | Horizontal abduction | $-Z_e$ | Posterior | Valgus |

**RESULTS AND DISCUSSION:** See Figure 3. Compressive force and horizontal adduction torque were exerted at the shoulder joint during the completing throwing motion. And the compressive force was approximate zero around LFO, so was the horizontal adduction torque. The maximal compressive, anterior and superior forces were exerted during Thrust phase. The maximal magnitudes started increasing earlier for S1 before LFL. Also, the maximal external rotation, abduction and horizontal adduction torques were exerted in thrust. S2 had greater anterior and superior forces than S1 in delivery, which we supposed to be crucial at shoulder joint. Besides, S2's anterior and superior forces exerted around 70% of the throwing time interval, but S1's exerted around 50% of the throwing time interval. It meant that S1's acted too early. S2 had one peak external rotation torque in thrust around 90% of the throwing time interval, but S1 did not have. S1's peak external rotation torque showed up around 75% of the throwing time interval. It meant that S1's throwing arm rotated externally too early. The timing of the muscle action of the throwing arm was important.



(a) S1's forces at shoulder (b) S2's forces at shoulder

(c) S1's torques at shoulder (d) S2's torques at shoulder

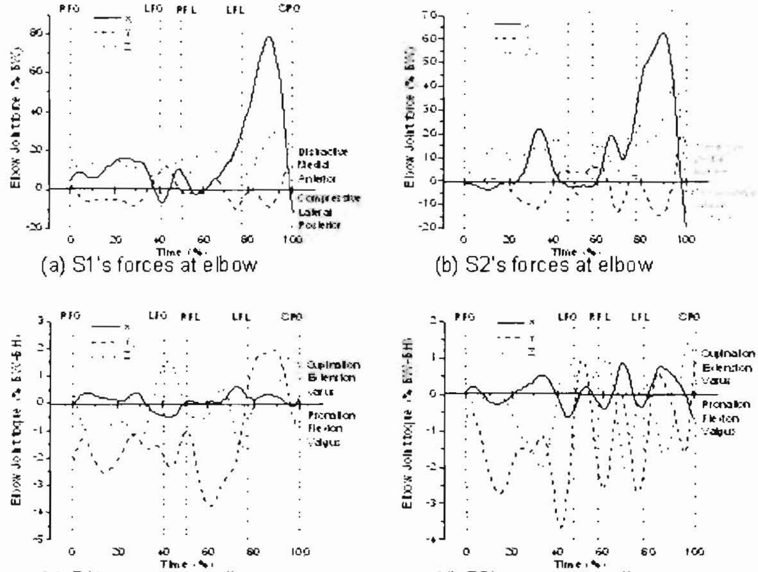
Figure 3: Forces and Torques at shoulder.

See Figure 4. S2 had one peak distractive force in delivery around 70% of the throwing time interval, but S1 did not have. S1 had one peak distractive force around 50% of the throwing time interval, and it was exerted too early compared to S2. Anterior force was exerted at the elbow joint during the completing throwing motion for both subjects. Both subjects increased lateral force gradually after LFL to the maximum, and then transferred it to medial force around 92% of the throwing time interval and reached the maximum just before SPO. The elbow joint torque of S2 fluctuated relatively greater than S1.

**Table 4 Maximal forces and torques at shoulder and elbow during Thrust phase.**

| Thrust phase | S1 | S2 |
|---|---|---|
| Maximum shoulder compressive force (% BW) | 94.78 | 87.12 |
| Maximum shoulder anterior force (% BW) | 41.31 | 42.52 |
| Maximum shoulder superior force (% BW) | 20.28 | 17.02 |
| Maximum shoulder internal rotation torque (% BW-BH) | 1.69 | 1.41 |
| Maximum shoulder abduction torque (% BW-BH) | 2.43 | 1.41 |
| Maximum shoulder horizontal adduction torque (% BW-BH) | 4.87 | 6.63 |
| Maximum elbow distractive force (% BW) | 78.59 | 62.16 |
| Maximum elbow lateral force (% BW) | 9.04 | 14.67 |
| Maximum elbow medial force (% BW) | 14.12 | 19.57 |
| Maximum elbow anterior force (% BW) | 32.34 | 40.22 |
| Maximum elbow supination torque (% BW-BH) | 0.58 | 0.77 |
| Maximum elbow extension torque (% BW-BH) | 1.96 | 0.60 |
| Maximum elbow varus torque (% BW-BH) | 1.83 | 1.58 |

In some shot put studies showed that great velocity-change of the shot happened during thrusting motion (Bartonietz, 1994; Palm, 1990). It meant that the shot putters exerted great force in thrust. Table 4 listed critical forces and torques exerted in thrusting motion. In thrust, shot putters underwent extremely great compressive and anterior forces on the shoulder and distractive and anterior forces on the elbow (Table 4). Also, the horizontal adduction torque was markedly great.



(a) S1's forces at elbow (b) S2's forces at elbow

(c) S1's torques at elbow (d) S2's torques at elbow

Figure 4: Forces and Torques at elbow.

**CONCLUSION:** In the throwing motion, compressive force and horizontal adduction torque were mainly exerted at the shoulder joint, while anterior force and flexion torque were mainly exerted at the elbow joint, i.e. the muscle efforts mainly contributed to those forces and torques aforementioned. Subjects' patterns of forces and torques were generally similar, but we found that the timing of anterior, superior forces, external rotation torque, and distractive force were markedly different. The beginner exerted his forces and torques too early, and he was suggested to adjust his muscle efforts according to the results. Due to the limitation of subject number, it's hard to conclude the general injuries of shot putting and to explain the information related to performances. More subjects included in such study would be more meaningful.

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