# CORRELATION BETWEEN THROWING MOTION AND MAXIMUM ELBOW VARUS TORQUE IN FEMALE PROFESSIONAL BASEBALL PITCHERS

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The purpose of this study was to identify the correlation between throwing motion and maximum elbow varus torque (MEV) in female professional baseball pitchers. Twelve pitchers without pre-existing pain were recruited. Ball velocity and pitching motion were measured. Ball velocity and, kinematic and kinetic data from each joint during the pitch were extracted to evaluate the correlation with MEV. There was no correlation between the fastest ball velocity and MEV. Sixteen kinematic and kinetic parameters were found to have significant correlations with MEV. Particularly, as trunk rotation angle to the non-throwing direction before lead foot contact (FC) increased, the MEV decreased. Rotating the trunk in the non-throwing direction before FC and immediately in the throwing direction after FC could be a key component of the throwing motion.

**KEY WORDS:** pitching, elbow pain, motion analysis, kinematics, kinetics, trunk rotation

**INTRODUCTION:** The Japanese women's professional baseball league was created in 2010, and women's baseball has become increasingly popular. According to the Japanese Women's High School Baseball Federation, the number of female high school baseball teams has been gradually increasing, from 5 teams in 2007 to 21 teams in 2016; a similar increase has been observed among female baseball players in the United States (Chu, Fleisig, Simpson, & Andrews, 2009). The Japanese women's national baseball team represents the highest level of women's baseball, as they have won the women's world cup championship four times.
During playing baseball, throwing disorders including elbow and shoulder pains often occur. In particular, medial elbow pain results from excessive valgus loading in baseball (Chen, Rokito, & Jobe, 2001). Therefore, minimizing the stress on the elbow joints is necessary to prevent throwing disorders. In male baseball pitchers, maximum elbow varus torque (elbow valgus

overload) during throwing has been previously associated with ball velocity (Fleisig, Barrentine, Zheng, Escamilla, & Andrews, 1999) and improper throwing motions (Aguinaldo, & Chambers, 2009). However, very little is known about the correlation between throwing motion and maximum elbow varus torque (MEV) in female baseball pitchers. The purpose of this study is to elucidate the correlation among throwing motion, including joint angle, joint angular velocity, and joint moment, and MEV in female professional baseball pitchers in order to improve exercise regimens and, coaching techniques, and to prevent injuries without reducing performance.

**METHODS:** Twelve pitchers without pre-existing pain were recruited from female professional baseball teams. Their mean age, height, and body mass were as follows: 23.9 ± 3.3 years, 164.7 ± 4.1 cm, and 61.2 ± 6.7 kg, respectively. According to the model of Plug-In Pitch (Wu et al., 2005) and Plug-In Gait, 9.5 mm spherical infrared reflective markers were located on the skin for each pitcher. After adequate warm-up, each pitcher threw a fastball at maximum strength. Ball velocity was measured using a high-performance sports radar gun (Stalker SOLO 2). Five trials of the pitching motion were captured using ten visible-red digital cameras interfaced with a three-dimensional motion analysis system (VICON NEXUS) and a floor reaction force measuring apparatus (AMTI). The data sampling rate was 500 Hz. The trial of the fastest pitch was analyzed.

To evaluate temporal parameters, the normalized pitching cycle was defined from the point of lifting the lead leg (separation from the floor surface; 0%) to the point of moving the throwing arm forward after ball release (100%). Local coordinate systems were defined for the foot, lower leg, thigh, pelvis, thorax, upper arm, forearm, and hand segments to calculate kinematic and kinetic data at the ankle, knee, hip, pelvis, spine, thorax, shoulder, elbow, and wrist joints. Torque for the throwing arm joints was calculated using the inverse dynamics technique. Ball velocity, kinematic and kinetic data of the each joint during the normalized pitching cycle were extracted to evaluate the correlation with MEV by using Pearson's correlation coefficient with the significance level set at $p < 0.05$.

**RESULTS:** The average value of the fastest ball velocity in all participants was 28.8 ± 1.7 m/s. The average of MEV generated on the throwing arm just before maximum shoulder external rotation was 49.5 ± 10.2 Nm (5.0 ± 0.8%Body Weight × Body Height). The point of the highest lead leg lift, maximum hip abduction of the trail leg, lead leg foot contact (FC), trail leg separation from the floor surface (TLS), maximum shoulder external rotation (MER), and ball release (BR) were 37.0%, 80.4%, 81.6%, 85.6%, 87.6%, 88.8% of the normalized pitching cycle, respectively. There was no correlation between the fastest ball velocity and MEV ($r$ = 0.17, $p$ = 0.61). Sixteen kinematic and kinetic parameters were found to have significant correlations with MEV (Table 1). In particular, before FC, the spine rotation angle relative to the direction of throwing ($r$ = 0.83, $p$ = 0.01) and shoulder horizontal adduction angular velocity

($r$ = 0.82, $p$ = 0.01) had the highest correlation with MEV.

**Table 1**

**Kinematic and Kinetic Parameters Significantly Correlated With Maximum Elbow Varus Torque**

| Parameter | % PC | $r$ (max value) |
|---|---|---|
| Before FC | | |
| Hip external rotation angle of the lead leg | 75.2-77.6 | 0.59 |
| Spine rotation angle to the direction of throwing | 78.8-83 | 0.83 |
| Thoracic rotation angle to the direction of throwing | 80-80.6 | 0.60 |
| Shoulder abduction angle | 77.8-80 | -0.63 |
| Shoulder horizontal adduction angular velocity | 77.4-80.2 | 0.82 |
| Shoulder abduction angular velocity | 80.2-83.4 | 0.77 |
| Elbow extension angular velocity | 77.4-80 | 0.70 |
| Knee extension moment of the trail leg | 79.2-83.2 | -0.66 |
| After FC | | |
| Shoulder horizontal adduction angle | 81.8-82.6 | 0.61 |
| Hip adduction moment of the trail leg | 83.4-84.6 | 0.61 |
| Before MER | | |
| Pelvic anterior tilt angle | 83.8-97.6 | -0.58 |
| Spine flexion angle | 84.2-86.4 | 0.64 |
| Elbow extension angle | 82.6-86.2 | 0.81 |
| Forearm pronation angle | 84.8-86.6 | 0.66 |
| After BR | | |
| Pelvic rotation angular velocity to the direction of throwing | 91.8-92.8 | 0.60 |
| Spine flexion angular velocity | 91.8-92.6 | -0.66 |

**DISCUSSION:** The average value of the fastest ball velocity (28.8 m/s) and MEV (49.5 Nm) in this study were similar to those of the female baseball pitchers playing at the national competition level (26.8 m/s and 46 Nm, respectively) reported by Chu (2009). Thus, the level of performance of the pitchers in our study is likely equivalent to that of those playing at the national competition level.

The fastest ball velocity of female professional baseball pitchers was not correlated with MEV. In male baseball pitchers, MEV has been previously associated with ball velocity (Fleisig, Barrentine, Zheng, Escamilla, & Andrews, 1999) and improper throwing motions (Aguinaldo, & Chambers, 2009). Therefore, Improper throwing motions might increase MEV.

Half of the sixteen parameters showed significant correlation with MEV before the FC. In particular, the spine rotation angle relative to the direction of throwing had the highest correlation with MEV. Male baseball players who initiated trunk rotation before FC had

significantly higher elbow varus torque than those who rotated afterward (Aguinaldo, & Chambers, 2009). Therefore, rotating the trunk in the non-throwing direction before FC and immediately in the throwing direction after FC could be a key component of the throwing motion. The second highest correlation with MEV was shoulder horizontal adduction angular velocity in this study. Increasing horizontal shoulder adduction angular velocity would indicate generating the energy with the throwing arm. During arm cocking, a pitcher who excessively adducts the shoulder horizontally increases elbow varus torque (Fortenbaugh, Fleisig, & Andrews, 2009). The body might compensate for the deficiency of generating the energy with the lower body and trunk by generating the energy with the throwing arm. Generating the energy with the throwing arm could lead to increased stress at the elbow joints.

**CONCLUSION:** This study indicated that the spine rotation angle relative to the direction of throwing had the highest correlation with MEV. Therefore, rotating the trunk in the non-throwing direction before FC and immediately in the direction of throwing after FC could be a key component of the throwing motion among female baseball pitchers to prevent elbow injuries and maintain high levels of performance. Generating the energy with the throwing arm as the compensation for the deficiency of generating the energy with the lower body and trunk could lead to increased stress at the elbow joints. Female baseball pitchers should focus on strengthening trunk muscles and practicing pitching that utilize the kinetic chain to transfer the energy from pelvis and trunk to the throwing arm.

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