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BALL VELOCITY AND ELBOW LOADING IN FASTBALL PITCHING

Xavier Gasparutto[1], Erik van der Graaf[2], Dirkjan Veeger[1,2], Frans van der Helm[1]

[1]Sports Engineering Institute, Delft University of Technology, Delft, The Netherland
[2]MOVE Institute, Vrije Universiteit Amsterdam, Amsterdam, The Netherland

Among baseball players, the pitchers are the most prone to injuries. These injuries occur mainly at the medial part of the elbow and at the shoulder. It is widely accepted that high joint loading are linked to overuse injury for repetitive motion. At maximal exo-rotation (MER), the elbow maximal abduction moment is predominantly counteracted by the ulnar collateral ligament and causes great stress on this structure. The aim of this study is to investigate the relationship between the elbow maximal abduction moment, ball velocity and technique. Thirteen elite pitchers participated in this study. Elbow maximal abduction moment was computed by an inverse dynamics method. Results indicate that the mean maximal abduction moment of the forearm on the upper arm was 41±9Nm and can be reduced without hampering ball velocity by lowering the elbow flexion angle at MER.

KEY WORDS: baseball pitching, injury, elbow loading, ball velocity

INTRODUCTION: In baseball, pitchers are the players that are most prone to injury. Indeed, between 1989 and 1999, 48% of injured players in MLB were pitchers (Conte et al., 2001). In those 48%, the shoulder and elbow were most frequently injured with respectively 28% and 22% of the days spent injured. In a longitudinal study over 2 years with 298 youth pitchers between 8 to 12 years old, Lyman et al. (Lyman and Fleisig, 2001) showed that 32% of the pitchers had shoulder pain (29% in superior aspect) and 25% had elbow pain (68% on the medial side). These injury rates are very high and occur at any age, thus efforts should be made to reduce those rates.

It is widely accepted (Whiteley, 2007) that the minimisation of the loading that occurs at the shoulder and elbow during pitching is a key factor to prevent injuries. To convince the pitchers to use their recommendation, sport scientists need to show the pitchers that performance will not be affected by the recommendations. Thus, this study aims at exploring the relationship between the maximal loading of the medial aspect of the elbow, ball velocity and pitching technique. The elbow loading is defined as the abduction moment of the lower arm on the upper arm as it is predominantly balanced by the ulnar collateral ligament where the flexion and pronation-supination moment are mainly balanced with muscle actions. A previous study (Gasparutto et al., 2016) has shown that the maximal peak of abduction moment at the elbow occurs at shoulder maximal exo-rotation (MER) during pitching. Thus, we will focus on this phase of pitching.

METHODS: *Measurements:* 8 pitchers from the Dutch AAA team (age: 16.1 ± 0.7years, size: 1.82 ± 0.08 m, weight: 76.9 ± 8.1 kg) and 5 pitchers from the Dutch A team (age: 29.6 ± 4.9 years, size: 1.92 ± 0.03 m, weight: 91.6 ± 6.8 kg) participated in this study. The Faculty of Human Movement Sciences' local ethical committee approved this research project. Informed consent was signed by the participant and/or their legal tutor. Pitchers were equipped with skin markers on the full body. Only the upper limb (UL) and thorax markers where used for this study. Four markers were taped on the thorax (Incisura Jugularis, Xiphoid Process, 7th Cervical Vertebrae and 10th Thoracic Vertebra), and six were taped on the throwing upper limb (Acromion, Medial and Lateral Humeral Epicondyle, Radial and Ulnar Styloid, Interphalangealis Proximal III). The pitchers performed five fastball pitches from a pitching mound. Three pitches per player were used, selected on the basis of the quality of kinematic data. The motion of the markers was recorded by a 10-camera (T40S, 100Hz) VICON system.

Rigid-body model: A rigid-body model of the upper limb and thorax was used. The proposal from the ISB (Wu et al., 2005) was used for the definition of the local coordinate systems (LCS) and joint coordinate systems (JCS) (fig. 1). The first axis of the JCS of the elbow is the estimated elbow flexion-extension axis (linked to upper-arm segment), the second axis is the adduction-abduction axis (floating axis) and the third axis is the pronation-supination axis (linked to the forearm segment). The gleno-humeral (GH) joint position, the position of the segment centres of mass, the segment masses and the segment matrices of inertia were determined with regression equations (Dumas et al., 2007). The wrist, elbow and GH joints were modelled as spherical joints. However, the GH joint position with respect to the thorax was not constrained and thus, the shoulder joint also had three degrees of freedom in translation. These translations model the motion of the scapular girdle in a simplified way.

The ball was modelled as a homogeneous sphere of 145g and 36.8mm radius which is in accordance with the Major League Baseball (MLB) rules. The ball centre of mass was assumed to be overlapping with the hand centre of mass. The ball release (BR) was modelled by linearly decreasing the ball mass (from 100% to 0% of mass) during the 20ms before ball release. This time period was the mean value of the last half of the acceleration phase of the upper limb. The ball velocity was estimated by the maximal velocity of the marker fixed on the Interphalangealis Proximal III.

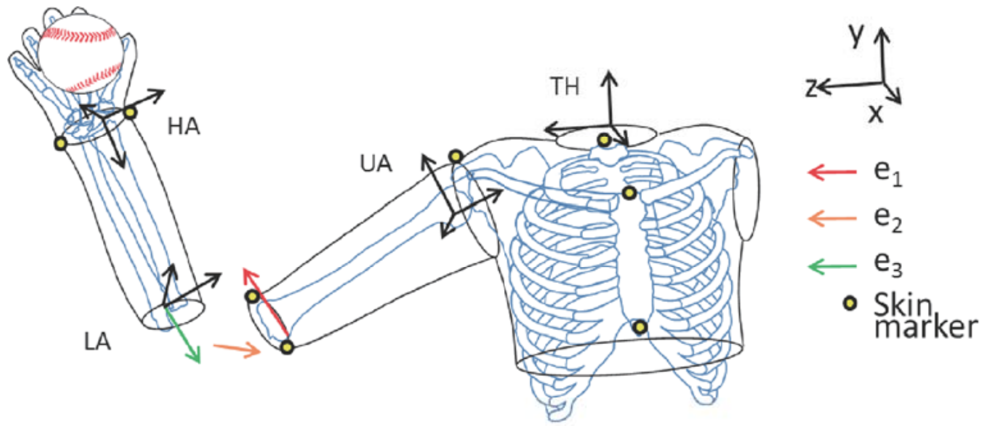

Fig1: Local Coordinate Systems of the upper limb and thorax & Joint Coordinate System of the elbow joint

Inverse dynamics: Inverse dynamics was performed iteratively using the wrench and quaternion method (Dumas et al., 2004) to determine the net actions (force and moment) at the wrist, elbow and shoulder. The elbow adduction-abduction moment of the lower arm on the upper arm was computed as the orthogonal projection of the net moment on the second axis of the elbow JCS, i.e. the adduction-abduction axis. For comparison among pitchers with various mass and size, dimensionless elbow moments $\bar{\mathbf{M}}_E$ (eq. 1) were computed by dividing the elbow moment $\mathbf{M}_E$ by the ratio r_M:

$$(1) \qquad \begin{cases} \bar{\mathbf{M}}_E = \mathbf{M}_E / r_M \\ r_M = L_{UL} \,.\, m_p . g \end{cases}$$

L_{UL} is the length of the throwing upper limb, m_p the mass of the pitcher and g the norm of the acceleration of gravity. This dimensionless moment was used for the correlations.

Correlation: Linear correlation was performed for two outcome measures: ball velocity (in mph according to MLB records) and $\bar{\mathbf{M}}_E^{abd}$ the elbow dimensionless abduction moment at MER; and three predictors: $\bar{\mathbf{M}}_E^{abd}$, the elbow flexion angle at MER and the shoulder exo-rotation at MER. This leads to five combinations. The linear correlation was expressed as:

(2) $$Outcome = a \times predictor + b$$

Where a and b are constant value determined by the regression process.

RESULTS:

During the first phase of the pitch (windup and stride) between 0 and 500ms, the elbow abduction moment is low (fig. 2). It increases strongly during the arm cocking phase that end with the maximal shoulder exo-rotation (between 500ms and 540ms) to reach the maximal abduction peak at MER (41±9Nm). It decreases during the arm acceleration phase that ends at ball release (600ms) with an adduction peak (-11±7Nm). A second abduction peak (13±6Nm) appears during the deceleration phase (600ms to 670ms). The mean maximal flexion and pronation moment were 46±9Nm and 4±2Nm respectively. These peak values occurs at 10ms before ball release and 10ms after ball release respectively.
The regression results (Table.1) showed no correlation between the ball velocity and the elbow dimensionless moment (R = -0.02), no correlation between the ball velocity and the elbow flexion angle (R = -0.06), weak correlation between the ball velocity and the shoulder maximal exo-rotation (R = 0.27), weak correlation between the elbow dimensionless moment and the shoulder maximal exo-rotation (R = -0.26) and a moderate positive correlation (R = 0.53) between the elbow dimensionless moment and the elbow flexion angle.

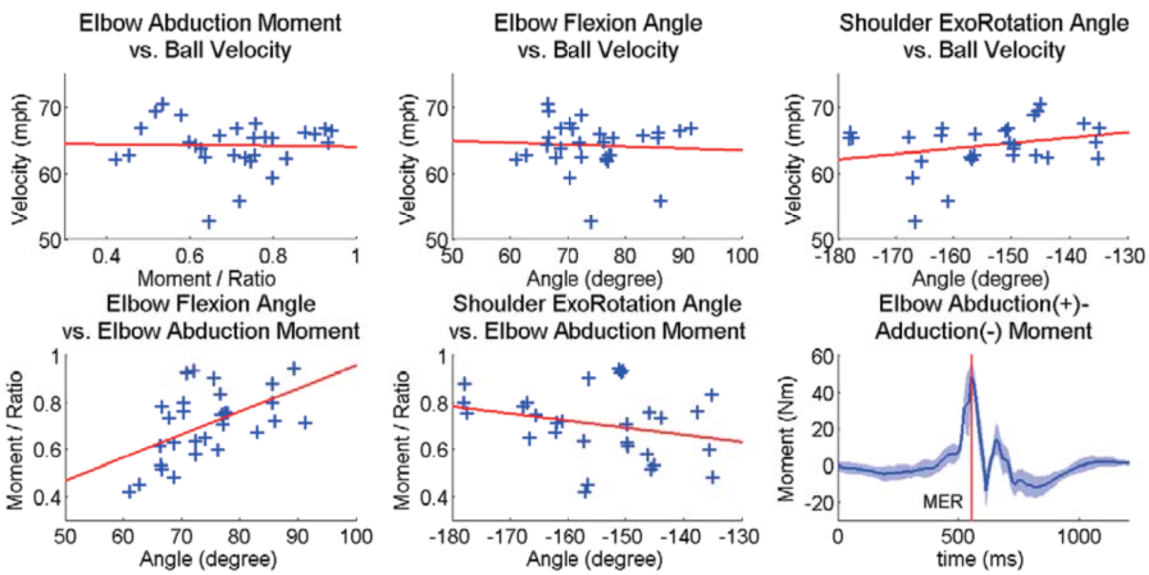

Figure 2: Linear regression vs. data points, and mean ± 1SD Elbow Abduction(+)/Adduction(-) dimensionless moment during pitching

DISCUSSION & CONCLUSION:

The mean maximal abduction moment was 41±9Nm. This value is comparable to the previous study of Aguinaldo and Chambers (Aguinaldo and Chambers, 2009) that showed mean abduction moment value of 50±29Nm. The maximal flexion motor moment had the same order of magnitude but the pronation moment was 10 times smaller than the maximal abduction moment.

This study showed that the elbow maximal abduction moment is not related to the ball velocity, thus it appears to be possible to lower this load and keep a high ball velocity. Lowering the maximal abduction moment could decrease the load on the ulnar medial ligament and help reducing the elbow injury rate and the elbow pain experienced by the pitchers (68% of elbow pain is localised on the medial part (Lyman and Fleisig, 2001)). The elbow abduction moment link with the elbow flexion angle has been shown with a positive correlation of 0.53 and the flexion angle of the elbow at maximal exo-rotation is not linked to ball velocity.

It appears that for a fast and safe throw the pitchers could lower their elbow flexion angle during the cocking phase to reduce the loading in the elbow without losing ball speed. In further study, to give more weight to this recommendation, more pitchers should be included and the relation between the elbow abduction moment and the ulnar collateral ligament strain should be explored.

Table 1: R is correlation coefficient and $Outcome = a \times predictor + b$

Outcome	Ball Velocity	Ball Velocity	Ball Velocity	$\bar{\mathbf{M}}_E^{abd}$	$\bar{\mathbf{M}}_E^{abd}$
Predictor	$\bar{\mathbf{M}}_E^{abd}$	Elbow Flexion	Shoulder ExoRot	Elbow flexion	Shoulder ExoRot
R	-0.02	-0.06	0.27	0.53	-0.26
a	-0.01	-0.03	0.08	0.53	-0.13
b	64.5	66.2	76.5	-1.7e-3	25e-3

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