THE ROLE OF PELVIS AND THORAX ROTATION VELOCITY IN BASEBALL PITCHING

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The objective of the present study was to examine the relative timing of pelvis and thorax rotations in achieving high throwing velocities in baseball pitching. During the preseason, a kinematic analysis was performed on eight pitchers. Peak angular velocities of the pelvis and thorax were determined and separation, defined as the time between the moments of maximal rotation velocity of the pelvis and thorax, was calculated. By themselves, maximal pelvis and thorax rotation velocity were not associated with throwing velocity. Separation was positively and significantly associated with throwing velocity. Results indicate that the relative timing of pelvis and thorax peak rotation velocity in pitching fastballs in baseball is a determinant of throwing velocity in skilled pitchers.

KEYWORDS: *biomechanics, kinematics, performance, pitching, separation*

INTRODUCTION: Throwing fast is the result of a movement in which the whole body is involved. The total body contribution has been described in different overhead throwing sports as the so-called "kinematic chain" (Fradet et al., 2004),(van den Tillaar & Ettema, 2009),(Wagner, Buchecker, von Duvillard, & Muller, 2010),(Putnam, 1993). It is, therefore, not surprising that throwing velocity is associated with several kinematic parameters not limited to those of the shoulder and arm (Stodden, Fleisig, McLean, & Andrews, 2005a),(Werner, Suri, Guido, Meister, & Jones, 2008a),(Wight, Richards, & Hall, 2004). Pelvis and thorax peak rotation velocities have been studied before (Oliver & Keeley, 2010; Stodden, Langendorfer, Fleisig, & Andrews, 2006; Werner, Suri, Guido, Meister, & Jones, 2008b) (Matsuo, Escamilla, Fleisig, Barrentine, & Andrews, 2001; Stodden, Fleisig, McLean, & Andrews, 2005b). However, those studies did not examine the timing of both peak rotation velocities, which is important from the viewpoint of the kinematic chain. The present study is aimed at the time interval between the peak rotation velocity of the pelvis and the peak rotation velocity of the thorax, which we define here as separation (figure 1).
The objective of the present study was to investigate whether pelvis and thorax peak rotation velocity and separation are associated with throwing velocity in fastball pitching. It was hypothesized that peak rotation velocity of the pelvis and thorax and separation are positively associated with throwing velocity.

METHODS: Eight pitchers of the Dutch AAA team (age 16.1 SD 0.7 years, stature 181.7 SD 7.9 cm / 5'11'' SD 3'', bodyweight 76.9 SD 8.1 kg) participated in this study. Measurements were performed in the Adidas MiCoach Performance Centre in Amsterdam. A 10-camera (T40S, 100Hz) VICON motion capturing system was used to record 3D marker positions. All players performed at two recording session. Position data of the markers were exported from VICON and all calculations were performed in Matlab (The MathWorks, Inc, Natick, Massachusetts, USA). Before processing, landmark coordinates were splined with the standard Matlab cubic spline interpolation function for missing data and filtered with a 4th order low-pass recursive filter at 12.5 Hz to reduce the effects of sampling error. Segment local coordinate systems (LCS) were defined for the thorax and pelvis (Wu et al., 2005). Segment angular velocities were directly calculated from the rotation matrices following Zatsiorski (Zatsiorski, 1998);

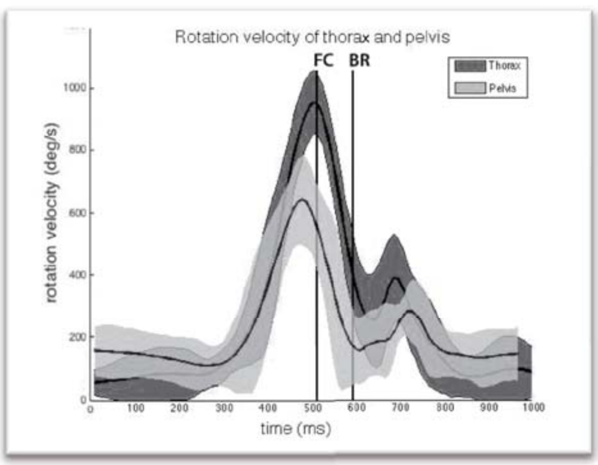
$$\breve{\omega} = 0.5 * \left(\left(\dot{R} \times R' \right) - \left(R \times \dot{R}' \right) \right), \quad \omega = \begin{bmatrix} \breve{\omega}(3,2) \\ \breve{\omega}(1,3) \\ \breve{\omega}(2,1) \end{bmatrix}. \qquad \text{(Eq. 1)}$$

R = rotation matrix expressing the orientation of the segment relative to a global coordinate system; $\dot{R}$ = the numerical derivative of rotation matrix R. []' = transposed rotation matrix. $\breve{\omega}$ = 3x3 skew-symmetric matrix containing the three angular velocity components around the three main axes. ω = 3x1 rotation velocity vector [x,y,z]'.
The magnitude of the angular velocity was calculated as the norm of the angular velocity vector:

$$\omega_{total} = [\omega(3,2)^{\wedge 2} + \omega(1,3)^{\wedge 2} + \omega(2,1)^{\wedge 2}]^{\wedge 0.5}. \qquad \text{(Eq. 2)}$$

Throwing velocity was calculated as the linear velocity of a marker attached to the tip of the middle finger of the throwing hand in the direction of throwing (x-axis).
Three fastball pitches per pitcher per recording session were used for the statistical analysis. The associations were explored with simple linear regression analysis using GEE (Generalized Estimating Equations (Liang & Zeger, 1993)) in SPSS (v 21.0.0.1, IBM Corporation, Armonk, NY, USA). The GEE was used to account for the dependency of the three repeated measurements within subjects and sessions. The general simple linear regression equation was:

$$outcome = b_0 + b_1 * predictor \qquad \text{(Eq. 3)}$$



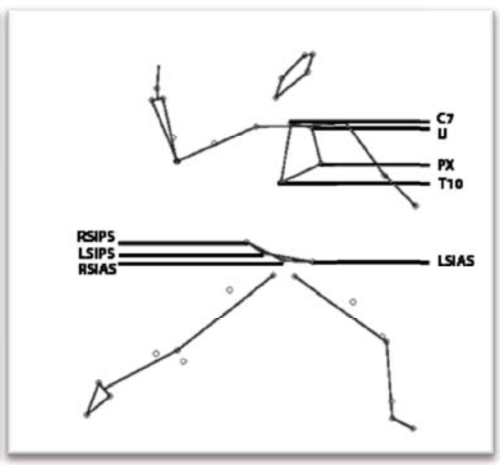


Figure 1 Average rotation velocity profile of thorax and pelvis from all 8 pitchers, surrounding areas are +/- 2 SD. Vertical lines are front foot contact (FC) and ball release (BR). Rotation velocity profiles of different pitches are synchronized at peak rotation velocity.

Figure 2 Marker set-up.

RESULTS: Separation was significantly associated with throwing velocity (b1 = 0.096, 95% CI 0.065-0.126). Based on the results of the regression analysis, for an increase in throwing velocity of 1 mph, separation would have to increase with 10 ms on average. Within this group of young elite pitchers, pelvis and thorax peak rotation velocity were not associated with throwing velocity. Within this group of young elite pitchers, pelvis and thorax peak rotation velocity were not associated with throwing velocity (figure 2).

DISCUSSION: The results of the present study demonstrate that separation is positively associated with throwing velocity. The theory of the kinematic chain predicts that to create maximal end point velocity of a system, segments of the body need to rotate in a sequential fashion, instead of increasing rotation velocities of all segments at the same time. This sequential order of rotation of the segments suggests that rotation velocity is increased from one segment to the next segment. The results of this research could mean the body needs time to transfer the rotation velocity from pelvis to thorax. This relationship between throwing velocity and separation between segments has recently also been reported in a study by Sgroi et al. (Sgroi et al., 2015). It should be kept in mind however, that there is likely to be an optimum for separation and that the GEE predictions should not be extrapolated to far. It remains a challenge to determine what the optimal separation is. Calculation of the power flow from segment to segment could give insight into the energy transfer between these segments, and thus the contribution of the individual segments to the velocity of the distal segment.

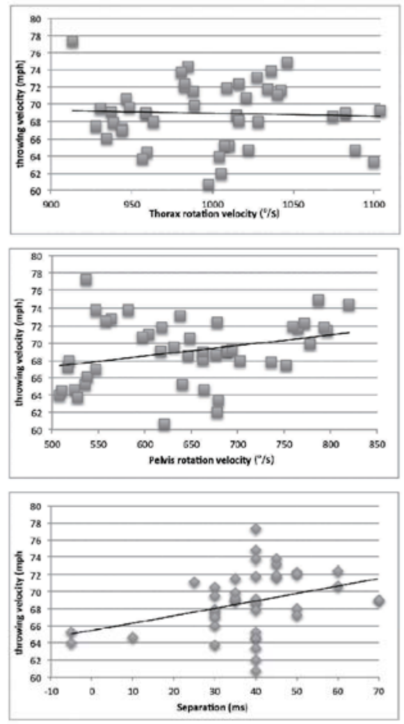


Figure 3 Associations between (A)thorax and (B)pelvis rotation velocity, (C)separation and velocity.

CONCLUSION: The relative timing of the moments of pelvis and thorax peak rotation velocity in pitching fastballs in baseball is associated with throwing velocity in skilled pitchers. Separation of segmental peak rotations deserves to be focused on in scientific research as well as in developing training programs in baseball pitching. In developing learning strategies special attention could be given to the interval between the pelvis and thorax rotations. During training, focus could be on using first the hips to rotate and let the trunk follow the movements of the hips.

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