Baseball Pitchers’ Kinematic Sequences and Their relationship to Elbow and Shoulder Torque Production

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Background & Purpose

• **Kinematic Sequence** = the sequential timing pattern of peak angular velocities of body segments during a pitch
  
  • Provides insight to segment position and motion control that drives the kinetic chain.
  
  • Previous publications report an ideal Kinematic Sequence (KS) where the timing of each body segment’s peak angular velocity occurs in a proximal-to-distal (PDS) pattern resulting in greater ball velocity and reduction in throwing arm injury risk.\(^1\),\(^2\)
    
    • A recent study revealed that baseball pitchers perform a variety of KSs.\(^3\)
  
  • High elbow valgus, external rotation and extension torques are associated with increased vulnerability to joint injury, but to date there is no known investigation of the relationship of Kinematic Sequences and throwing arm joint torques.\(^4\),\(^5\)

The **purpose** of this study was to:
1) identify the number of different KSs performed by each pitcher and
2) compare elbow valgus and shoulder external rotation (ER) and extension (Ext) torques between the 3 primary KSs performed during the fastball pitch.
Materials and Methods

Subjects:
• 14 male collegiate pitchers
• Mean age 20.57 ± 1.91 yrs

Test Protocol:
• Full body kinematics captured via Vicon MX 3D motion analysis system (360 Hz)
• Each pitcher threw 10 - 12 fastballs from a standardized pitching mound the full 60’ 6” length over home plate to strike zone target
• A Stalker ATS 5.0 radar gun recorded pitch speed

Biomechanical calculations:
• 15 segment 6 degree-of-freedom model
• Upper body segments were defined in accordance with International Society of Biomechanics definitions\(^6\)
Kinematic Sequence

The timing of peak angular velocities for 5 body segments (Pelvis, Trunk, Arm, Forearm and Hand) were recorded to generate each pitch’s Kinematic Sequence (Figure 1).

Kinematic Sequence Naming

Each Kinematic Sequence was named in reference to the ideal PDS: The first segment noted out of order in the PDS sequence (Figure 2).

Figure 1. Altered distal upper extremity Kinematic Sequence

Figure 2. Body positioning at the time of peak angular velocity for the 5 segments of the Altered distal upper extremity Kinematic Sequence.
Data Analysis

Data:
- Strike zone fastball pitch trials were included in analysis
- Average fastball velocity = 34.51 m/s (± 1.99)
- 119 fastball pitches (average of 8.5 ± 2.71 pitches per player)
- Kinematic body segment position data calculated in Visual 3D™ (C-Motion)

Shoulder Variable Definitions:

External Rotational torque: The required force to rotate the humerus about the vertical axis Externally (+) in the Z plane (N-m).

Extension torque: The required force to rotate the humerus about the frontal axis into Flexion (+) or Extension (-) in the X plane (N-m).

Analyses:

ANCOVA statistical analyses were performed to compare joint torques across KS groups with ball velocity as a covariate.
Analyses of the 119 fastball pitches revealed:

- 13 different Kinematic Sequences (KS)
- An average of $3 \pm 1.41$ different Kinematic Sequences performed per pitcher
- NONE of the kinematic sequences followed true ideal Proximal-to-Distal order
- Three primary Kinematic Sequences were performed and named (Figure 3):

  1. Altered Distal Upper Extremity (UE) KS
     Pelvis $\Rightarrow$ Trunk $\Rightarrow$ Arm $\Rightarrow$ Hand $\Rightarrow$ Forearm
  2. Altered Proximal Upper Extremity KS
     Pelvis $\Rightarrow$ Trunk $\Rightarrow$ Forearm $\Rightarrow$ Hand $\Rightarrow$ Arm
  3. PDS KS: closest KS to the ideal Proximal-to-Distal (PDS)
     Pelvis $\Rightarrow$ Trunk $\Rightarrow$ Arm $\Rightarrow$ Simultaneous Forearm & Hand

Figure 3. Number of pitches performed for three primary Kinematic Sequence patterns.
Analyses of the 3 primary Kinematic Sequences (n= 66):
Statistically significant differences across the sequences were noted for:

- Elbow valgus torque \[ F(62,2) = 8.785, \eta^2 = .221, p < 0.00 \]
- Shoulder external rotation (ER) torque \[ F(62,2) = 14.127, \eta^2 = .313, p < 0.00 \]
- Shoulder extension (Ext) torque \[ F(62,2) = 13.237, \eta^2 = .299, p < 0.00 \] (Figure 4)

Figure 4. Comparison of shoulder and elbow torques across the 3 primary KS sequences
* p< 0.05 established level of significance
Conclusions

- Our findings demonstrate that collegiate baseball pitchers performed an average of 3 different kinematic sequence patterns during fastball pitching.

- This is the first study to demonstrate a relationship between kinematic sequences (KS) and elbow and shoulder torque production.
  - As anticipated, the PDS KSs, the sequence most similar to the ideal proximal to distal sequencing, produced the least torque across the elbow and shoulder joints.
  - The Distal Upper Extremity KS was most common and generated the greatest shoulder extension torques.
  - The Proximal Upper Extremity KS demonstrated the greatest elbow valgus and shoulder external rotation torques.
Discussion

• All fastball pitches are not the same. Each player throws different sets of pitches with different timings. In the small sample in this study, an average of 3 different timings (Kinematic sequences) were used for each player.

• Pitchers try to optimize the kinetic chain to harness power and efficiency. This is the first study to demonstrate that the concept of optimizing the Kinematic Sequence is indeed efficient with lower torques. The Kinematic Sequence most similar to the proximal-to-distal Kinematic Sequence produce decreased torques in the shoulder and elbow.

• Despite this, the most commonly performed Kinematic Sequences were not the ideal proximal-to-distal Kinematic Sequence and had greater associated torques.

• Further study of the influence of Kinematic Sequence patterns on joint torques in the baseball pitch may provide insight into pitching injuries and design of injury avoidance programs.
REFERENCES:


