A Unique Kinematic Model for Describing Glenohumeral Joint Motion during the Windmill Softball Pitch

Miller L, Richards J, Kaminski T, Royer T
Department of Health, Nutrition & Exercise Sciences
University of Delaware, Newark, DE

Abstract:

Clinical application of upper extremity joint angle calculations have proven challenging in biomechanics. Kinematic descriptions of joint angles provide the clinician the position of the joint during response to various stresses. It is therefore critical that joint angle calculations are both clinically applicable and accurate. Various models have been developed in biomechanics to explain glenohumeral joint angles, including Euler angles, helical (screw) axis angles, and spherical coordinate systems. Applications of these methods have been established in baseball literature, resulting in a consistent utilization of the internal rotation/horizontal flexion/internal rotation (YZY) Euler sequence. Accepted methods of kinematic analysis are not yet defined with regards to softball pitching. The circumduction motion of the glenohumeral joint during a softball pitch challenges current methods of calculations. The windmill motion of the softball pitch requires full circumduction of the humerus, with varying degrees of internal and external rotation depending on pitch type. The circumduction motion of the humerus lends itself to errors during calculations using standard Euler and Helical models. The kinematic model for the shoulder used in this project was unique in describing shoulder motion without conventional Euler rotation sequences. This model employed a combination of plane deviation angles and internal/external rotation angles derived from Helical methods. The use of planar deviations provides a clinically useful means of describing the orientation of the humerus relative to the trunk, is a consistent method throughout the entire motion, and offers no discontinuities or errors when compared to three-dimensional motion. While it is not customary to utilize separate methods to explain kinematic data, the windmill pitch presents complications that require this practice.

Purpose:

To describe a unique kinematic model to calculate glenohumeral joint angles during a ballistic motion: the softball pitch; while also providing clinically useful measures of joint angles not previously reported in the literature.

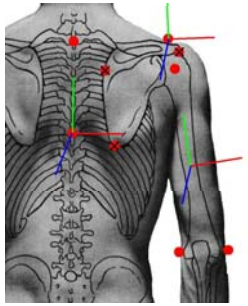

Figure 1. Coordinate systems for the trunk, shoulder, and upper arm

Background:

- Clinical application of a glenohumeral kinematic model necessitates acknowledgement of both Codman's paradox and the issue of gimbal lock [1].
- Euler angles are one common method for calculation of joint angles; however, the sequence-dependent nature of those calculations can cause discrepancies, particularly at the glenohumeral joint. [1,2].
- Helical (screw) axis calculations are time-dependent, describing instantaneous rotation and translation about a single axis [1]. Helical motion is limited to defining distinct motion consistent with clinical articulations [1]. When combinations of motion, such as circumduction in the glenohumeral or hip joint are present, Helical motion is inefficient at distinguishing paths of motion.
- The spherical rotation coordinate system proposed by Cheng [2] also provides a model for the glenohumeral joint. However, implementation of this algorithm resulted in mathematically similar results to the International Shoulder Group (ISG) recommendation for calculating glenohumeral joint angles: the Euler YZY (Abduction/Internal Rotation/Abduction) sequence.
- For overhead shoulder motion, the Euler sequence of YZY is a common method for calculating kinematic data. This rotation sequence commonly used to examine baseball pitching. Softball pitching, however, presents a motion that is not well-defined by current methods of joint angle calculation.
- The windmill motion of the softball pitch requires full circumduction of the humerus, with varying degrees of internal and external rotation depending on pitch type. The circumduction motion of the humerus lends itself to errors during calculations using standard Euler and Helical models.

Methodology:

Subjects:

- Eleven subjects (age= 15.4 ± 1.2 yr. old; height= 159.2 ± 10.8 cm; mass= 55.9 ± 8.4 kg)
- The protocol was institutionally approved and all subjects provided written assent with corresponding parental consent.
- All subjects were right-handed pitchers.

Procedures:

- Eleven Eagle Digital cameras (Motion Analysis Corporation, Santa Rosa, CA), recording at 240 Hz,
- EVaRT 5.1.1 software was used for determination of the 3-D coordinates for each of the markers.
- After warm-up, subjects were fitted with a marker set representing a modified version of the International Shoulder Group (ISG) recommendations for biomechanical analysis of the upper extremity (Figure 1)
- Five trails were collected for each subject.
- Markers were tracked using EVaRT 5.1.1 software to correctly identify position in the volume.
- A custom software program developed using Lab View 8.21 (National Instruments, Austin, TX) was developed and used to calculate all kinematic data.

Results:

- Planar deviations described the position of the upper arm relative to anatomical planes of motion positioned at the glenohumeral joint center.
- The internal/external rotation motion was described using a Helical calculation.

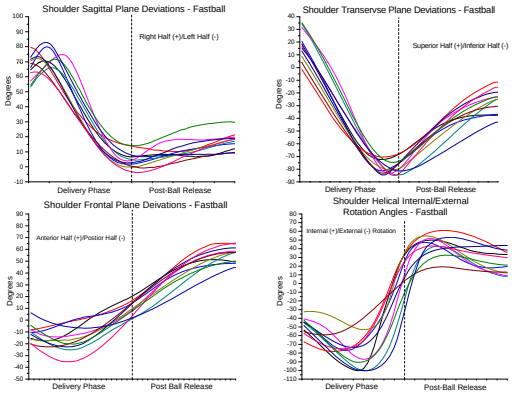

Figure 2. Planar deviations and helical I/E rotation angles for the fastball

Discussion:

- Shoulder motion during the windmill pitch is poorly described using conventions of Euler and Helical calculations.
- Due to the discontinuity seen in the flexion/extension and abduction/adduction curves and also given the misrepresentation of internal/external rotation, the XZY Euler rotation was not an appropriate convention to describe the entire windmill pitch.
- A planar deviation model was created to describe shoulder motion during a windmill pitch.
- Model does not include internal/external rotation motion.
- Internal/external rotation of the shoulder during the acceleration phase was isolated independent of other arm motions.
- When compared to the Helical calculations it appears that while Helical misrepresents abduction/adduction and horizontal flexion/extension, it provides a reasonable estimate of internal/external rotation.

Conclusions:

- While it is not customary to utilize separate methods to explain kinematic data, the windmill pitch presents complications that require this practice.
- This model was also unique in describing shoulder motion without conventional Euler rotation sequences.

References:

1. Hill AM, et al. *Gait & Posture*, **27**, 177-188, 2008
2. Cheng PL. *Ann Biomed Eng* **28,** 1381-1392, 2000