BIOMECHANICAL CHANGES IN A PROFESSIONAL BASEBALL PITCHER: EARLY VS. LATE INNINGS

Tricia Murray, Sherry Werner and Richard Hawkins
Steadman♦Hawkins Sports Medicine Foundation, Vail, CO USA

The purpose of the study was to investigate the effects of extended play on the kinematic and kinetic parameters of the baseball pitch in order to gain a better understanding of injury mechanisms and preventive strategies. Four professional pitchers were videotaped with high-speed (120 Hz) cameras during the second, fourth and sixth innings of the same game. Video data were digitised for one fastball for each inning, and kinematic and kinetic parameters were calculated from the 3D coordinate data. Comparisons between the pitches were based on standard deviations found for the same parameters in a similar study of 40 professional pitchers. Shoulder and elbow ranges of motion, peak varus torque, shoulder and elbow distraction and the rates of angular velocities were among the variables to show significant change.

KEY WORDS: kinematics, kinetics, baseball pitching.

INTRODUCTION: The baseball pitch has been described as one of the most dynamic movements of the upper extremity (Dillman et al., 1993). During a pitch the shoulder complex can experience angular velocities in excess of 122 rad/sec (7000 deglsec) and compressive forces in excess of 100 % body weight (Feltner and Dapena, 1986). The elbow joint is also under significant strain with maximum velocities reaching 40 rad/sec (2300 deg/sec) and compressive forces of up to 780 N (Werner et al., 1993). Not surprisingly, injuries to pitchers are common.

Studies have examined the kinematics and kinetics of the upper extremity in order to better understand the mechanisms responsible for pitching injuries (Barrentine et al., 1996). Previous studies have been limited, however, by the environment in which the data were collected. To the authors' knowledge this report represents the first attempt to examine professional pitchers in a game situation. Moreover, it seeks to investigate the effects of extended play on the kinematic and kinetic parameters of the baseball pitch. It is hoped that a better understanding of injury mechanisms and preventive strategies may be achieved.

METHODS: Data were collected during the 1998 Cactus League in Arizona as part of Spring Training for Major League Baseball. The method of data collection involved the use of three 120-Hz cameras (PEAK Performance Technologies). Two cameras were placed in the right and left field bleachers, and were used depending on whether the pitcher was right or left handed. The third camera was used for all throwers, and was placed above and behind home plate in the press box. In order to calibrate the pitching area, a 24-point calibration frame (PEAK Performance Technologies) was videotaped simultaneously by all three cameras. Horizontal and vertical reference markers were also placed on the pitching mound in order to create a pitching relevant reference frame. The four pitchers were then videotaped from the front and appropriate throwing side. The mass of the 22.9 cm circumference ball was 142 g. Fast balls were chosen for analysis.

A PEAK Performance Motion Measurement system was used to manually digitise the locations of twenty landmarks for each subject. The time interval from 50 ms prior to the instant the ball left the glove until 50 ms after ball release was studied. The Direct Linear Transformation method was used to obtain three-dimensional coordinate data for the ball and each body landmark. Data from the two cameras were synchronised on the instant of ball release. Coordinate data were conditioned with a Butterworth fourth order, zero lag digital filter (cutoff = 10Hz). All coordinate data were expressed in terms of the mound relevant reference frame. .

Video data were digitised for one fastball for the second, fourth and sixth innings, and kinematic and kinetic parameters were calculated from the 3D coordinate data. Over 50 kinematic parameters were calculated. The forces and torques at the shoulder and elbow joints of the throwing arm were calculated according to the methods described by Feltner and Dapena (1986). In order to normalize data between subjects, forces were expressed as a percentage of body weight and torques as a percentage of the product of body weight and height. A standard statistical software package (Systat, Inc.) was used to further reduce the kinematic and kinetic data. Comparisons between the pitches were based on standard deviations found for the same parameters in a similar study of 40 professional pitchers.

RESULTS AND DISCUSSION: Differences were seen between selected kinematic and kinetic parameters between the second and fourth innings as well as the second and sixth innings. Comparisons were made to descriptive statistics from a study of 40 professional pitchers. Shoulder and elbow ranges of motion, peak varus torque, shoulder and elbow distraction and the rates of angular velocities were among the variables to show significant change.

Significant changes (those in excess of one standard deviation of the 40 pitcher population) between the second and sixth innings were chosen for analysis. Specifically, ball velocity decreased by 4 m/sec from the second to sixth innings. Maximum hip angular velocity decreased by 3.4 rad/sec (194 deg/sec). Maximum hip rotation occurred between stride foot contact (SFC) and maximum shoulder external rotation (MER).

Although not significant, it was found that between the second and sixth innings, the pitchers increased the time interval from SFC to MER, and in order to keep the overall timing of the pitch the same, they compensated by decreasing the time from MER to the instant of ball release (REL). Due to the extended number of innings it appeared that the timing of the pitch was altered. The cocking phase became longer and as a result the delivery phase was rushed. The hip rotation speed decreased because the hips still needed to rotate through the same range of motion, and since the cocking phase increased in time, angular velocity had to decrease.

The angular velocity of the shoulders decreased more than twice that of the hips. Nlaximum shoulder angular velocity decreased by 7.5 rad/sec (432 deg/sec). Overall, it appeared that trunk rotation speed decreased as a result of extended play. This may indicate a breakdown in the transfer of power from the lower to the upper trunk. Maximum horizontal adduction (near REL) increased by 0.2 rad (9 deg) from the second to sixth inning. It appeared that because of a lack of trunk rotation the arm needed to move relative to the body to allow the pitcher to hit the release point. Elbow angle at REL decreased by 0.5 rad (31 deg) as a result of extended play. Thus, the elbow was more flexed in the sixth inning as compared to the second. In the second inning, the elbow was 0.2 rad (10 deg) shy of full extension and 0.7 rad (40 deg) shy in the sixth inning. This may be due to the fact that between the second and sixth innings the time from MER to REL decreased. In other words, the pitcher was rushed and did not have enough time to fully extend the elbow at REL.

Shoulder distraction stress at REL decreased by 167 N. This drop in distraction force at REL may be attributed to increased elbow flexion and horizontal adduction, both of which protect the shoulder by creating a smaller moment arm. Maximum elbow distraction, which also occurred near REL, decreased by 250 N by the sixth inning. This decrease is also most likely due to increased elbow flexion at REL. Maximum elbow flexion torque decreased by 41 Nm. A decreased range of elbow extension required less torque to control elbow motion. Peak elbow valgus torque increased by 21 Nm and may be due to the altered timing sequence of the pitch. An increased time in the cocking phase, and the subsequent decrease in time for the delivery phase, placed the elbow at greater risk of valgus extension overload. Maximum horizontal adduction torque decreased by 110 Nm from the second to sixth innings. This decrease may be attributed to decreased trunk rotation and the rushed delivery phase. Lastly, maximum intemal rotation torque increased by 19 Nm. This torque aids in decelerating the arm, and by rushing the delivery phase elbow extension was limited and therefore may have caused an increase in this internal rotation torque.

CONCLUSION: It appears that when a pitcher becomes fatigued over the course of six innings, the timing sequence is the first thing to suffer. Ultimately, performance then suffers as well. In elite athletes the timing sequence between stride foot contact and release has very low variability. Therefore, any extra time spent in the cocking phase is made up in the delivery phase. Although the timing of the phases of the pitch were not significant parameters, they approached significance and help to tie the results together. The time of the cocking phase (from SFC to MER) increased between the second and sixth innings. If a pitcher was fatigued, it took him longer to get his arm to MER. The extra time spent in the cocking phase tended to deteriorate the energy transfer between the feet and the trunk. Because of the reduction in trunk speed, horizontal adduction was increased in an effort to hit the release point. Trying to make up for the extra time spent in the cocking phase, the delivery phase was rushed and the pitcher did not have enough time to fully extend the elbow at REL. The final result was a decrease in ball speed, which ultimately represents a decrement in performance.

The reduction in shoulder distraction force at REL that occurred between the second and sixth innings can be attributed to the increased horizontal adduction and elbow flexion. Despite the reduced distraction force at the shoulder, which is believed to stress the rotator cuff, the increased maximum internal rotation torque could be stressing the cuff an equal amount during the follow through.

This study provides preliminary guidelines for clinicians regarding the changes in range of motion, joint stress and speeds of movement with extended play in a professional baseball pitcher. It is hoped that a better understanding of injury mechanisms and preventive strategies may be achieved through this type of study.

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