A THREE-DIMENSIONAL CINEMATOGRAPHIC ANALYSIS OF THE BASEBALL PITCH

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Introduction

Pitching is one of the most important aspects of the game of baseball. However, only a small number of quantitative biomechanical studies have been reported (Feltner & Dapena, 1986). Specifically, there have been few studies of the motion of the forearm and wrist joints during a pitching action. The purpose of this study is to record the changes in angles and angular velocities of the shoulder, elbow, radioulnar and wrist joints during a baseball pitch. In this study, three dimensional (3-D) high-speed cinematography was used to record the fastball pitches of varsity baseball pitchers.

Methods

The subjects were three male varsity baseball pitchers with a mean height of 1.78 m and a mean weight of 67 kg. A fastball pitch with the maximum effort of each subject was filmed with two phase-locked cameras (Photo-Sonics 1PL) operating at frame rates of 200 fps (Fig. 1). Two small reference markers were fixed on the hand and forearm of the throwing arm (Fig. 2). The mass of the markers were 12 g and 8 g, respectively. The direct linear transformation (DLT) method (Abdel-Azis & Karara, 1971) was used for 3-D space reconstruction from 2-D images of each film. Digital filtering (16 Hz) was used to smooth the time-dependent coordinates of the reference markers, and the subject's landmarks (Winter, 1981). Using these 3-D coordinates, changes in the angles of the following joint movements were calculated throughout the pitching action (Fig. 3):

(1) abduction/adduction angle at the shoulder joint,
(2) horizontal abduction/adduction angle at the shoulder joint,
(3) internal/external rotation angle at the shoulder joint,
(4) flexion/extension angle at the elbow joint,

(5) pronation/supination angle at the radio-ulnar joint,
(6) radial/ulnar flexion angle at the wrist joint, and
(7) palmar/dorsal flexion angle at the wrist joint.

Fig.1) Diagrammatic view of the testing environment.
(S.Sakurai, et al.)

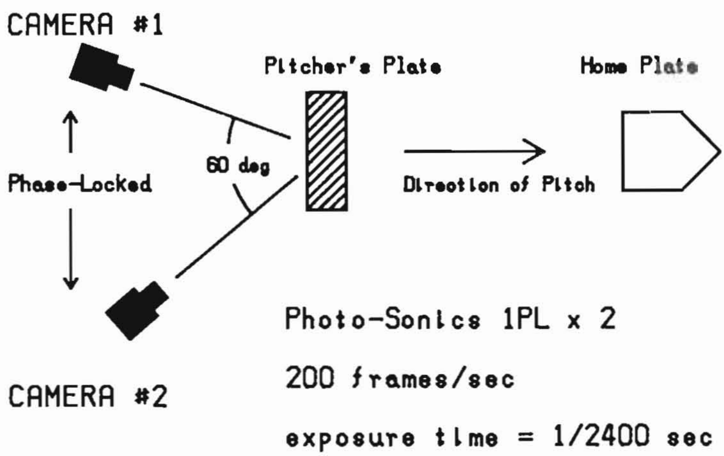


Fig.2) Sketches of the small reference apparates for detecting the motion of forearm and hand.
(S.Sakurai, et al.)

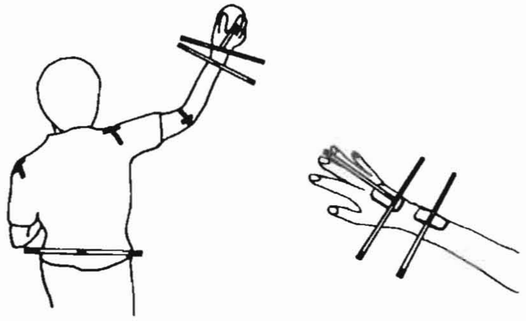
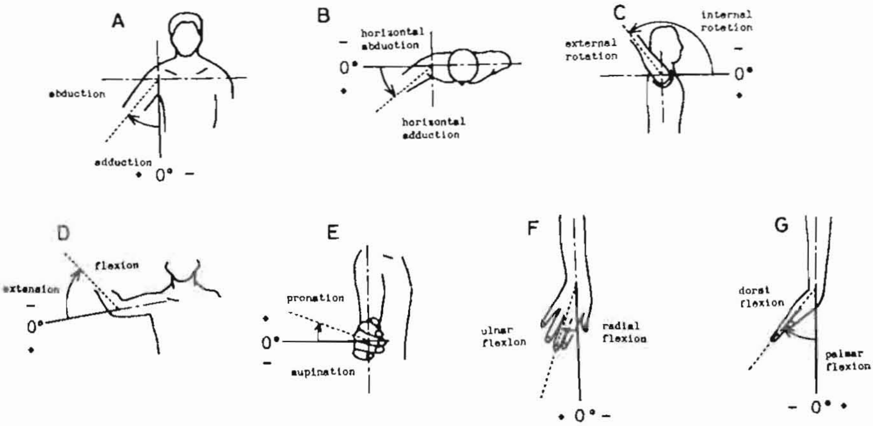


Fig.3) Definitions of the angles of seven joints.

(S.Sakurai, et al.)

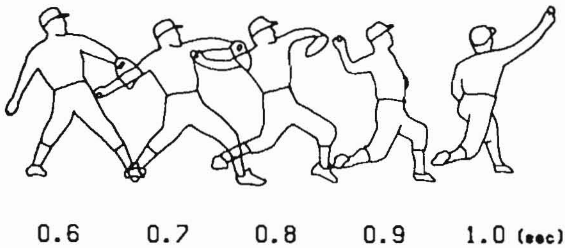


Results and Discussion

The average speed of the ball at release was 33.1 m/s. The sequence of a pitch from subject A is shown in Fig. 4. For convenience, the time t + 1.00s was arbitrarily assigned to the instant of ball release. In this study, analysis of the trials began at an instant of t = 0.60 s (0.40 s before ball release) and ended at t = 1.03 s.

Fig.4) Sketches of a sequence of a pitch of subject A.

(S.Sakurai, et al.)



The projection path of the ball from the ground is shown in Fig. 5. There were different patterns for each individual. Fig. 6 and Fig. 7 show the angle changes and angular velocity changes of the seven joints.

Fig.5) The projection of the path of the ball on the ground.

(S.Sakurai, et al.)

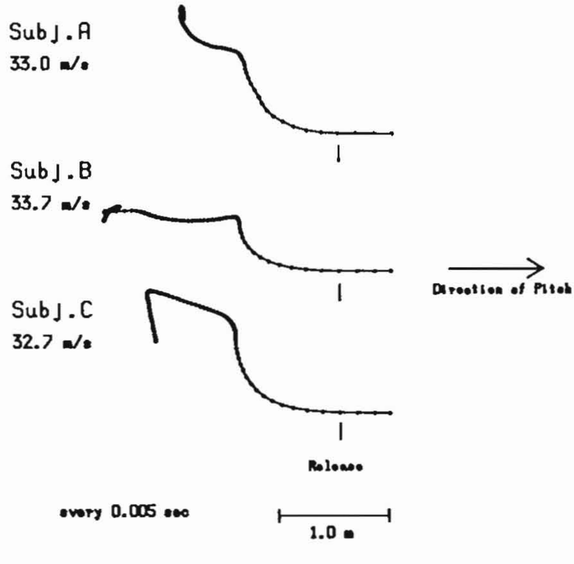


Fig.6) The changes of each joint angle.

(S.Sakurai, et al.)

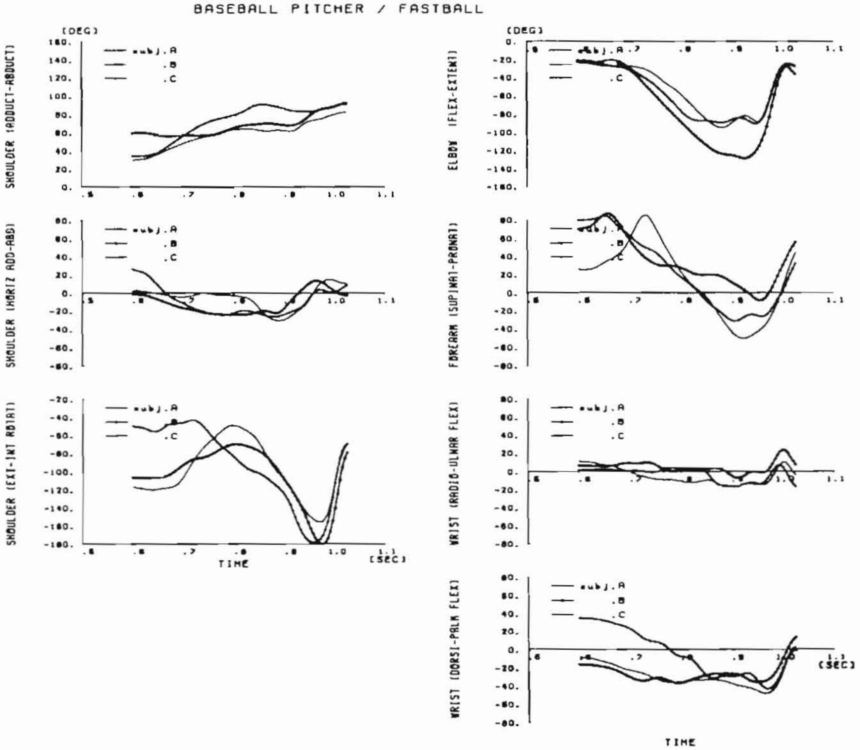
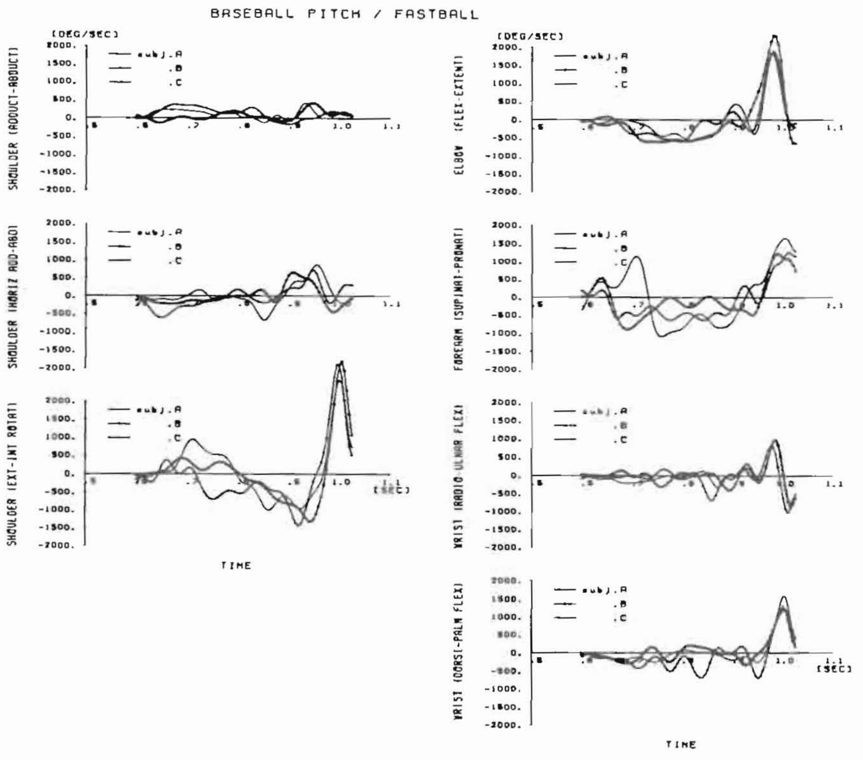


Fig.7) The changes of angular velocity of each joint.

(S.Sakurai, et al.)



The shoulder continued to abduct gradually during the pitching motion. The upper arm was abducted at 0.30 s, 0.06 s before the ball was released. At the instant of release it was somewhat horizontally adducted. The shoulder joint reached its maximum external rotation (-170 deg $\pm$ 10 deg) at an instant of t = 0.97 s, and then it began internal rotation. The peak angular velocity of internal rotation was 2900 deg/s $\pm$ 200 deg/s, and it coincided with the instant of the ball release.

At t = 0.60 s to 0.70 s, the elbow joint was in an extended position. It reached its maximal flexion at 0.05 s before the ball release, and then it extended. The peak angular velocity for elbow extension was 2030 deg/s $\pm$ 220 deg/s, and it occured shortly before the ball release (t = 0.99 s).

The forearm was in a pronated position 0.30 s to 0.40 s before release. It was supinated gradually until t = 0.95 s, and then it was prontated. The peak velocity of pronation was 1320 deg/s $\pm$ 220 deg/s

The range of motion for radial-ulnar flexion of the wrist joint is smaller than the other joints. The hand was slightly ulnar-flexed at the instant of release. The wrist joint continued dorsal flexion until t = 0.96 s, and then it began palmar-flexion. The peak velocity of palmar-flexion was 1360 deg/s $\pm$ 170 deg/s, and it coincided with the instant of ball release.

The results show that acceleration of the ball occurs following a counter movement against the direction of the throw at each joint. Such a pattern of body movement increases the range of the motion at each joint and incorporates the muscular reflex action and the stored elastic energy of the muscle being used. (Miyashita, et al. 1980).

Many researchers have reported that a skilled throwing movement consists of continuous movements of the body segments or joints. These movements start at the trunk and follow the order of: shoulder, elbow, wrist and ball. (Sakurai & Miyashita, 1983). Contrary to other findings, our results showed that the movements in the direction of the throwing occured almos simultaneously in the shoulder, elbow, radio-ulnar and wrist joints. The reason for this discrepancy may be due to the method of the analysis. Many joint actions participate in the throwing motion and as may be seen in the Fig. 5, 2-D procedures are insufficient for analyzing the motion of throwing.

Conclusions

The 3-D film analysis technique, with small markers on the hand and forearm, provides a useful tool for analyzing the kinematics of throwing motion.

References

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