THROWING ARM MOTION TO DETERMINE SPIN AXIS OF PITCHED BASEBALL

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The purpose of the present study was to investigate a throwing arm kinematics to determine the direction of spin axis of pitched baseball. The baseball was filmed immediately after ball release using a high-speed video camera (250 Hz). The direction of the spin axis and the spin rate were calculated based on the positional changes of the marks on the ball. The throwing motion was recorded with 3-D motion analysis system (Vicon), and angles of wrist flexion/extension, radial/ulnar deviation, and forearm pronation/supination were calculated as kinematic parameters. The direction of the hand segment in global reference frame was also obtained. The spin axis direction significantly correlated with the hand direction, while, there were no special relationship between the spin axis of the ball and joint angular kinematics obtained in this study. It follows from what has been reported that pitched ball trajectory is associated with attitude of the hand when a ball was released from the fingertip.

KEY WORDS: baseball, spin, kinematics.

INTRODUCTION: Kreighbaum (1978) proposed that the trajectory of a pitched ball is determined by; the initial linear and rotational velocities of the ball, the angle of release, the orientation of the ball's axis of rotation, and the air density. Several throwing studies have shown the mechanism to increase initial velocity. However, the studies how to apply spin to a ball have seldom been executed. The purpose of the present study was to investigate a throwing arm kinematics to determine the direction of spin axis of pitched baseball.

METHOD: Sixteen Japanese university baseball pitchers were used as subjects. All of them were classified as over-hand or three-quater-hand style pitchers. All testing was conducted in an indoor facility with a pitching mound. All subjects were instructed to pitch ten fast balls.

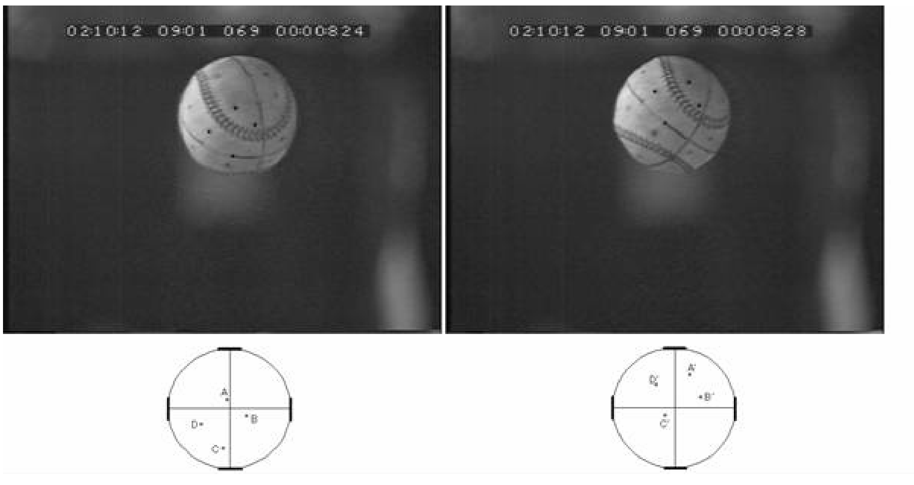

Figure 1: Video images used for calculating the direction of spin axis and spin rate (above). The schematic diagram of digitized points on the ball (below).

The baseball was filmed immediately after the ball release using a high-speed video camera (250 Hz), and the direction of the spin axis and the spin rate were obtained based on the positional changes of the marks on the ball (Figure 1, Jinji and Sakurai 2006). The direction of the spin axis was defined by two angles, θ_B (azimuth) and φ_B (elevation), an angle between spin axis and pitching direction (α_B) was also obtained (Figure 2). A trial for which

α_B value was the closest to the average α_B value for each subject was selected for the following analysis.

Reflective Markers were placed on the following locations of the pitcher's body: (a) greater trochanters bilaterally; (b) lateral tips of acromion bilaterally; (c) lateral and medial epicondyles of throwing arm; (d) radial and ulnar styloid processes of throwing arm; (e) head of the third metacarpal on the dorsal aspect of the throwing hand. A VICON motion analysis system (250Hz, 10cameras) was used to obtain the 3D location of the reflective markers.

Angles of wrist flexion/extension, radial/ulnar deviation, and forearm pronation/supination were calculated as kinematics parameters (Sakurai et al. 1993, Barrentine et al. 1998). $\underline{Z_W}$ was a vector from the throwing elbow joint to the throwing wrist joint centre, $\underline{Y_{temp}}$ was a vector from the ulnar wrist marker to the radial wrist marker, $\underline{X_W}$ was the cross-product of $\underline{Y_{temp}}$ and $\underline{Z_W}$, $\underline{Y_W}$ was redetermined as the cross-product of $\underline{Z_W}$ and $\underline{X_W}$ and used for all remaining calculations. $\underline{Z_H}$ was a vector from the wrist joint centre to the third metacarpal head, and $\underline{X_H}$ was the cross-product of $\underline{Y_W}$ and $\underline{Z_H}$. Then $\underline{Y_H}$ was defined as the cross-product of $\underline{Z_H}$ and $\underline{X_H}$.

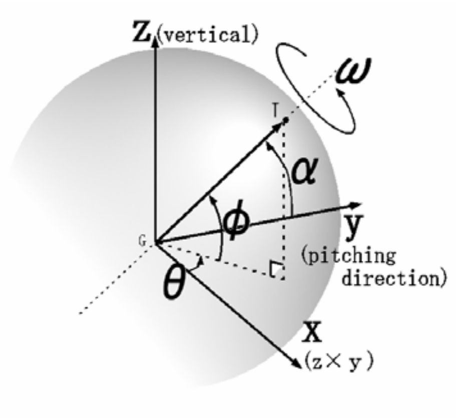

Figure 2: Definition of spin axis. The orientation of the angular velocity vector ω is specified by two angles φ and θ. α is angle between spin axis and pitching direction.

The direction of the hand segment ($\underline{Y_H}$ vector) in global reference frame was defined by two angles, θ_H (azimuth) and φ_H (elevation). An angle between $\underline{Y_H}$ vector and pitching direction (α_H) was also obtained.

RESULTS: The mean values of θ_B, φ_B, α_B and ω at release instant were 28.6 ± 12.4°, -25.0 ± 7.7°, 64.3 ± 11.9° and 31.9 ± 4.1rpm, respectively. The mean values of θ_H, φ_H and α_H at release instant were 9.3°, -38.0° and 83,1°, respectively. The angle changes in θ_H of two subjects whose α_B at release were largest (subj.N: 79.2deg) and smallest (subj B: 40.0deg) are shown in Figures 3. θ_H at release was significantly correlated with θ_B (r=0.717, Figure 4). Any anatomical joint angles did not significantly correlate with angles of spin axis.

Table 1 Results of ball and hand kinematics at the release instant

	velocity(m/s)	θ_B(°)	ϕ_B(°)	α_B(°)	ω (rpm)	θ_H(°)	ϕ_H(°)	α_H(°)
Mean	34.4	28.6	-25.0	64.3	31.9	9.3	-38.0	83.1
SubjA	34.2	27.6	-25.7	65.3	40.4	0.9	-38.7	89.3
SubjB	35.6	53.9	-18.4	40.0	36.3	18.0	-49.0	78.3
SubjC	32.2	42.1	-31.2	55.0	26.6	15.0	-44.9	79.4
SubjD	35.8	22.7	-30.5	70.6	32.4	7.7	-41.5	84.3
SubjE	36.4	28.3	-21.7	63.9	31.3	5.6	-31.4	85.2
SubjF	36.7	14.3	-29.1	77.6	34.8	7.7	-37.9	83.9
SubjG	34.4	32.7	-21.7	59.8	30.1	21.1	-54.5	78.0
SubjH	33.9	40.5	-24.7	53.9	34.7	24.9	-40.6	71.4
SubjI	34.2	44.4	-2.4	45.6	25.3	20.3	-30.7	72.6
SubjJ	34.4	35.4	-22.3	57.6	29.9	3.7	-33.4	87.0
SubjK	34.7	17.7	-35.9	75.7	27.5	2.6	-38.4	88.0
SubjL	35.6	17.1	-27.6	74.9	35.0	4.1	-40.8	86.9
SubjM	35.8	30.7	-26.9	62.9	34.0	9.5	-38.2	82.5
SubjN	32.5	12.6	-30.9	79.2	28.2	4.0	-22.9	86.3
SubjO	33.1	11.8	-19.5	78.9	34.7	3.2	-28.1	87.1
SubjP	31.4	25.4	-31.2	68.5	29.7	0.4	-36.5	89.7

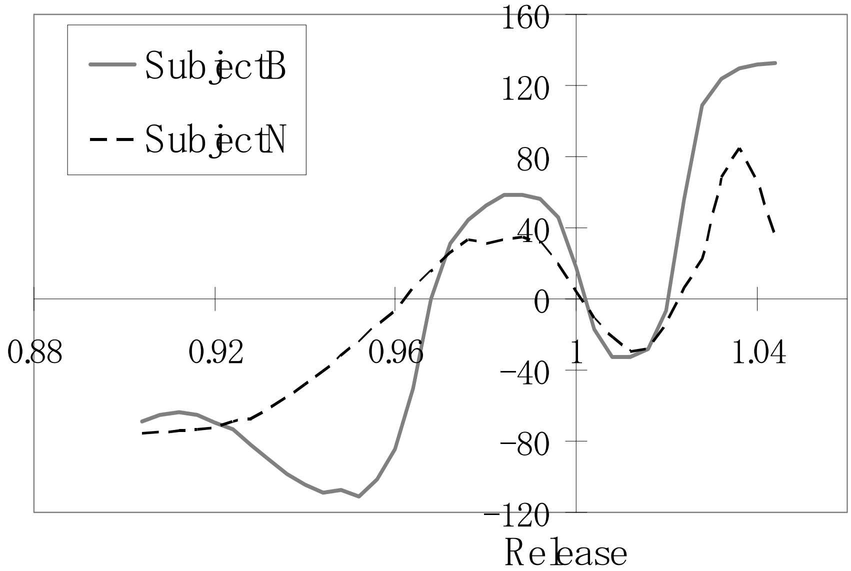

Figure 3: Angle changes in θH of two subjects whose αB at ball release were largest (subject N), and smallest (subject B).

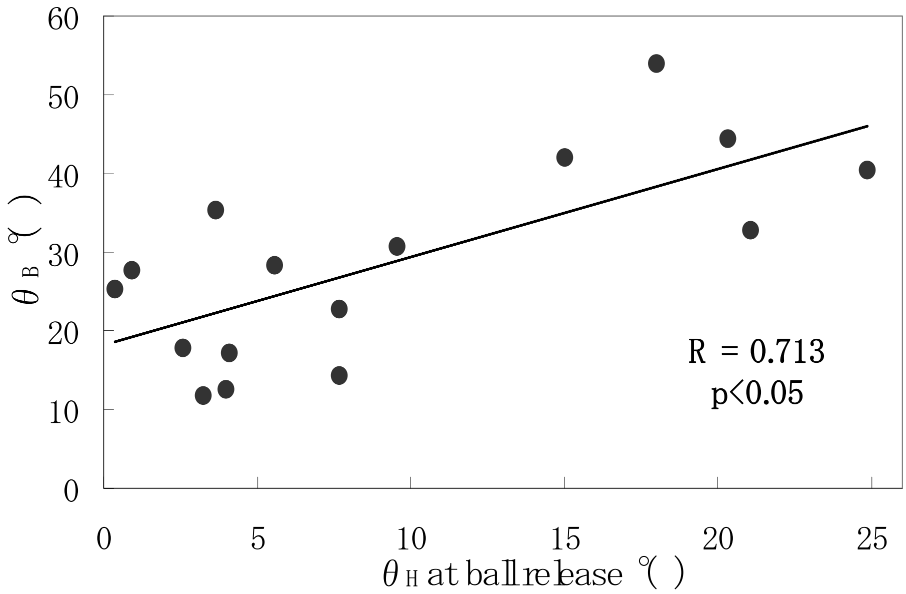

Figure 4: Relationship between θB and θH at ball release.

DISCUSSION: The direction of spin axis is one of the major factor in determination of pitched ball trajectory. Lift force of the pitched baseball is largest when the angular and translational velocity vectors are perpendicular to each other. It was found that pitched ball trajectory is associated with attitude of the hand when a ball was released from the fingertip. However, there were no special relationship between θ_B nor $\varphi_B$and joint angular kinematics obtained in this study, such as wrist flexion/extension, radial/ulnar deviation, and forearm pronation/supination. The spin axis and spin rate was not necessarily determined only by the attitude angle of the hand. We should investigate a throwing arm kinematics more thoroughly. In this study only a fast ball throwing motion was investigated. The methods used in this study can be widely applied. We need to apply this method to other pitches such as curve balls for better understanding of the mechanism that provides a spin to a ball.

CONCLUSION: It was found that a direction of spin axis (θ_B) is associated with an attitude angle of the hand (θ_H) when a ball was released from the fingertip. However, there were no special relationship between θ_B nor φ_B and joint angular kinematics In order to clarify the mechanism that provides a spin to a ball, we should investigate a throwing arm kinematics more thoroughly.

REFERENCES:

Barrentine, S.W., Matsuo, T., Escamilla, R.F., Fleisig, G.S., and Andrews, J.R. (1998). Kinematic analysis of the wrist and forearm during baseball pitching. Journal of Applied Biomechanics, 14(1), 24-39.

Jinji, T., and Sakurai, S. (2006). Direction of spin axis and spin rate of the pitched baseball. Sports Biomechanics, 5 (in press).

Kreighbaum, E.F., and Hunt, W.A. (1978). Relative Factors Influencing Pitched Baseballs. Biomechanics of Sports and Kinanthropometry, 227-236.

Sakurai, S., Ikegami, Y., Okamoto, A., Yabe, K. and Toyoshima, S. (1993). A three-dimensional cinematographic analysis of upper limb movement during fastball and curveball baseball pitches. Journal of Applied Biomechanics, 9(1), 47-65.