FACTORS DETERMINING THE SPIN AXIS OF A PITCHED FASTBALL

Tsutomu Jinji[1], Shinji Sakurai[2] and Yuichi Hirano[1]

Department of Sports Science, Japan Institute of Sports Sciences, Tokyo, Japan[1]
School of Health and Sport Sciences, Chukyo University, Toyota, Japan[2]

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INTRODUCTION: In order to make hitting more difficult for a batter, the pitcher introduces spin and alters the trajectory from a simple parabolic trajectory to one in which the aerodynamic force plays a significant role (Alaways and Hubbard, 2001). Although the direction of the spin axis greatly affects the lift force acting on the ball (Jinji and Sakurai, 2006), no study has been reported on how the spin axis of a pitched ball is determined in pitching motion. The purpose of the present study was to investigate the factors that determine the direction of the spin axis of the baseball. It is expected that movement of the upper extremity relates to the direction of the ball spin axis (Chin et al., 2009). The present study focused on the orientation of a pitching hand in a global coordinate system.

METHOD: Nineteen male baseball pitchers (height 176.2 ± 4.3 cm, mass 71.0 ± 7.4 kg) volunteered to participate. Fifteen subjects were right-handed, and four subjects were left-handed. All pitchers were regarded as over-hand or three-quarter-hand pitchers. Each pitcher performed pitching in an indoor pitching mound, pitched five to eight fastballs to a catcher 18.44 m away. A VICON MX motion analysis system (Oxford Metrics Inc.) was used to record the movements of the reflective markers attached to the pitcher's body (13 points) and the balls (4 points). The system operated 10 cameras at a sampling frequency of 1000 Hz.

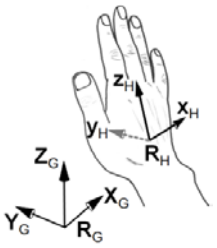

Figure 1. Definition of the global and local reference frames. R_G denotes the global reference frame; R_H, the hand reference frame.

For each pitcher, the trial in which the velocity of the pitched ball was found fastest was selected for analysis. Cardan rotation angles were used to define the orientation of the hand segment. The angles of the hand direction are designated right rotation/left rotation for the first rotation about the z_H axis, right sideways/left sideways for the second rotation about the y_H' axis, and backward tilt/forward tilt for the third rotation about the x_H'' axis (Fig. 1). For the analysis of the left-handed pitchers, a left-hand coordinate system was defined, with the Y_G and Z_G axes being the same as those of the right-hand coordinate system and the X_G axis directed opposite to that of the right-hand coordinate system.

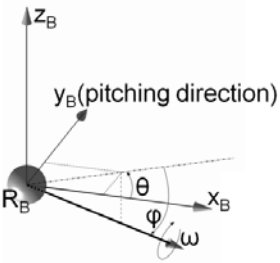

Figure 2. Definition of spin axis. The orientation of the angular velocity vector ω is specified by two angles φ and θ.

The angular velocity vector of the ball spin immediately after ball release (BRL) was calculated from the four hemispherical reflective markers attached to the pitched baseball; the calculation was performed with the method described by Jinji and Sakurai (2006). The direction of the angular velocity vector was expressed in the global reference frame, defined by the azimuth θ (the angle between X_B and the projection of the spin axis in the horizontal plane) and the elevation φ (the angle between the spin axis and the horizontal plane).

Pearson's product moment correlation coefficients were calculated to determine the relationship between the direction of the spin axis and the parameters representing the angles of the hand direction. The level of significance was set at 0.05.

RESULTS: The ball speed for the nineteen subjects was 34.0 ± 3.1 m/s (average ± S.D.). The spin rate was 27.4 ± 3.4 rps. The values of the angles θ and φ were 34.9 ± 14.1° and –28.4 ± 9.8°, respectively.

The hand was in the position of right rotation (18.2 ± 12.1°) at the maximum external rotation (MER) of the shoulder. The angle of right rotation attained the peak value at 12 ms before the BRL. Subsequently, the hand rotated to the left, and the ball was released with a right rotation (7.0 ± 12.1°). Further, the hand was in a position of left sideways rotation (–25.1 ± 10.2°) at the MER. Then it tilted to the right, and attainded the maximum value of right sideways rotation (41.6 ± 15.1°) at about time of BRL. In addition, the hand was in a position of backward tilt (107.8 ± 9.2°) at the MER. Then, it gradually tilted forward, and subsequently, the ball was released with a slightly backward tilt position (10.9 ± 11.4°) of the hand.
The angle of the spin axis θ exhibited the highest correlation with the angle of hand rotation at 6 ms before the BRL (r = 0.840, Fig.3). In addition, the angle of the spin axis φ exhibited the highest correlation with the angle of the hand‘s sideways rotation at 7 ms before the BRL (r = –0.725, Fig.4).

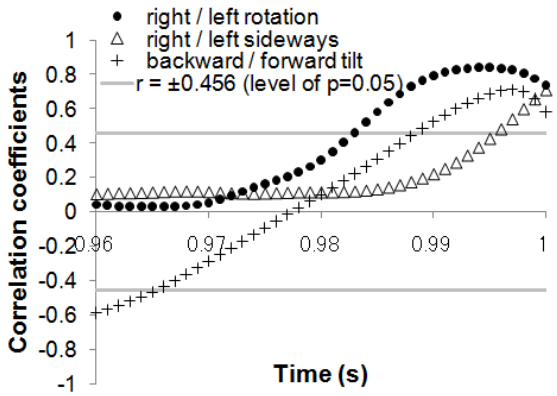

Fig.3: Changes in correlation coefficients between the direction of spin axis θ and orientations of the hand. The time of ball release is assigned t= 1.000 s.

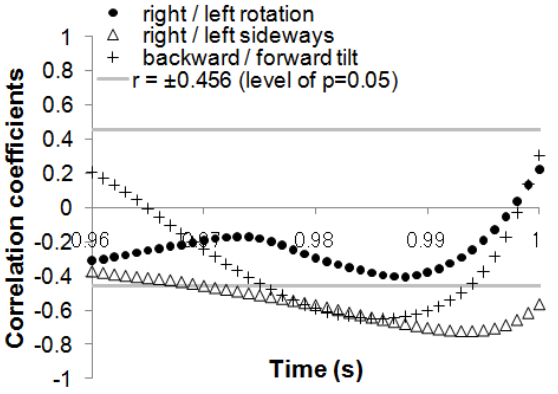

Fig.4: Changes in correlation coefficients between the direction of spin axis φ and orientations of the hand. The time of ball release is assigned t = 1.000 s.

DISCUSSION: Stevenson (1985) reported that the thumb of the throwing hand came off the ball at approximately 6 ms before the BRL. This instant of time is almost identical to the one when the angles of the spin axis have the highest correlation with the orientation of the hand in this study. As soon as the hand is partially open, the ball starts to roll or slide relative to the hand (Hore et al., 1996). Then, the ball rotates on the plane that is formed by the palm and fingers and is released from the fingertip. Therefore, the spin axis of the ball is parallel to the plane. It was found that the spin axis of a fastball was determined by these mechanisms.
The lift force of the pitched baseball is largest when the angular and translational velocity vectors of the ball are mutually perpendicular. In order to increase the lift force, the palm needs to face toward the home plate. On the other hand, there is a possibility of many types of balls with various spin axis directions and rotation speeds. Basically, it is expected that the direction of the spin axis is determined by the direction of the palm.

CONCLUSION: The orientation of the hand just before ball release was a significant factor in determining the direction of the spin axis.

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