BASEBALL SPIN AND PITCHERS' PERFORMANCE

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The motion of the ball thrown by a pitcher is influenced by three forces: gravity, drag force due to air resistance, and lift force which deflects a ball vertically or laterally due to ball spin. The lift force acting on the ball increases with spin rate and movement speed when the spin axis of the ball is orthogonal to the direction of ball movement. Among individual pitchers there were great variations in spin on their fastballs, both in spin rate and in direction of the spin axis. Ball spin rate was positively correlated with increases in distance from the optimal contact point of the swung bat (sweet spot) to the actual point of contact. That is, batters tend to hit under the ball when it has a high spin rate, even for balls of the same velocity. Abnormal or unique ball spin is an important aspect of superior performance for pitchers.

KEY WORDS: baseball pitcher, ball spin, performance.

The goal of baseball pitchers is to get batters out. To accomplish this, they throw many kinds of pitches. Among these are fastballs and various kinds of breaking balls such as curveballs and forkballs. Each type of pitch has a unique flight trajectory; for example, a curveball shows a larger amount of vertical drop as compared with a fastball (Johnson et al., 2001). Even the trajectories of pitches of similar speed, and expressed with the same word can be different between pitchers. These subtle differences can have a major influence on the pitcher's overall performance (Nagami et al., 2013). Thus, a particular individual's fastballs are typically distinguishable from those of other pitchers due to slight differences in lateral trajectory and/or the appearance of an upward "hop". In this article, we will focus on our recent experiments on ball spin in baseball pitching.

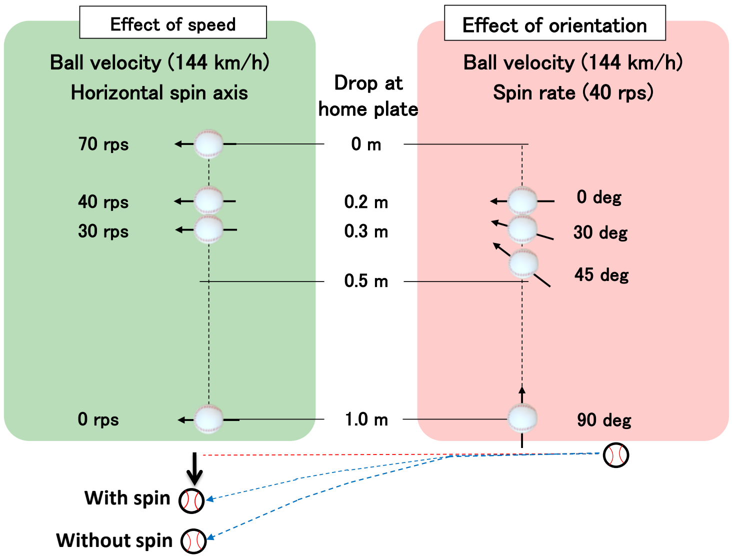

Figure 1. Effects of spin rate and axis orientation (view from the pitcher) on drop of a ball. The spin axis is assumed to be orthogonal to the direction of movement. A higher spin rate and more horizontal axis orientation lead to less drop. The data were supplied by Mizota T. (personal communication).

According to computer simulation and wind tunnel experiments on baseball spin (Mizota T, personal communication), a fast ball of 144km/s velocity with no spin drops about 1 m along the way from the pitcher to the home plate (Fig. 1). If this ball has backspin, then the amount of drop becomes less as spin rate increases. Note: from this point forward, spin will refer to backspin. Theoretically, a ball having a spin rate of 70 revolutions per second (rps) could reach the home plate with no drop, which never occurs for balls thrown by real pitchers. The amount of drop is also influenced by the orientation of the spin axis. A ball with a spin rate of 40 rps drops only 20 cm if the spin axis is horizontally oriented. It drops more as the axis tilts more, and when the axis is vertically oriented, the ball falls just like in free fall (no upward lift).

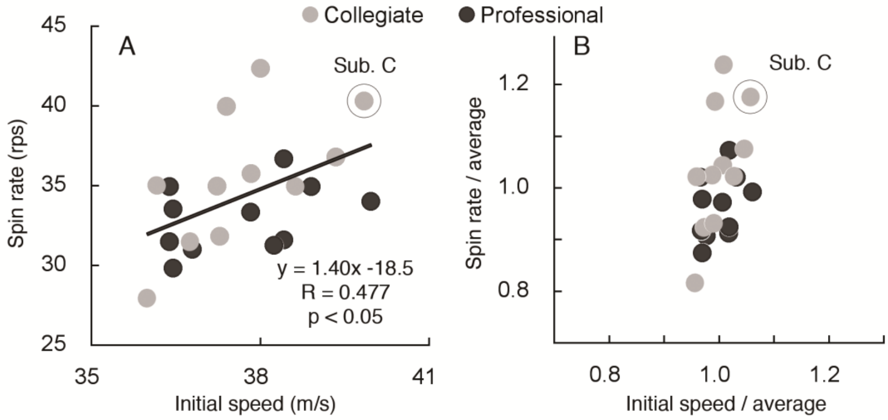

Figure 2. A) Relationship between initial ball speed and ball spin rate in elite pitchers. B) Variability of initial ball speed and ball spin rate. (From Nagami et al. 2011)

SPIN ON FASTBALLS: There have been few studies investigating the spin of a ball actually thrown by baseball pitchers. Jinji and Sakurai (2006) showed that the spin axes of fastballs thrown by collegiate pitchers were tilted vertically and horizontally. We recently examined the direction of the spin axes of fastballs thrown by 11 elite professional and 11 elite collegiate pitchers (Nagami et al., 2011). The video image of a ball being pitched was taken from the period just before release until 200 ms after release with a high-speed video camera at a rate of 1000 frames per second. A custom-made device was used to analyze the spin axis angle and spin rate. There was no significant difference in the spin rate or direction of the spin axis between the professional and collegiate pitchers. There was a positive correlation between initial ball speed and spin rate (Fig. 2A), in agreement with the results of Jinji and Sakurai (2006). It should be noted that spin rate was more variable across subjects as compared with ball speed (Fig. 2B).

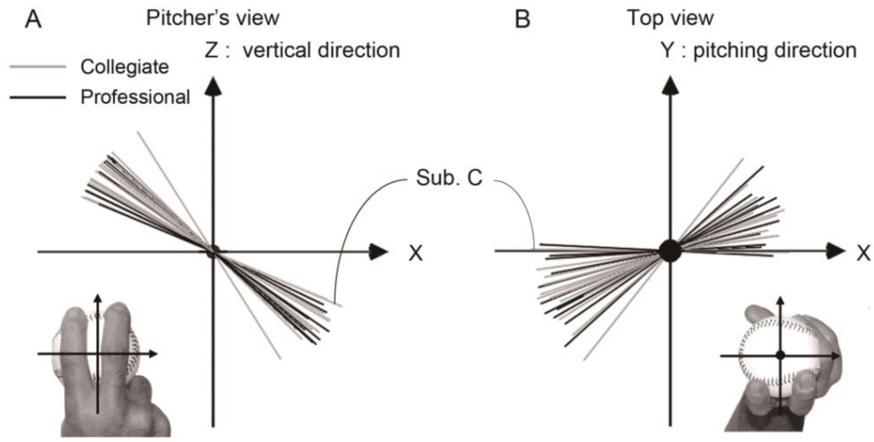

Figure 3. The direction of spin axes: A) view from pitcher, B) view from top. (From Nagami et al., 2011)

ORIENTATION OF SPIN AXIS: No pitcher throws fast ball with pure back spin, that is, spin axis is completely horizontal and perpendicular to the direction of motion (Fig 3). The direction of spin axis of fastball thrown by one of the collegiate pitcher (Sub. C in Fig. 3) was closer to the true back spin than those of any other subjects (Fig. 3). So his fastballs would have a larger upward lift force than fastballs thrown by the other pitchers with similar speed. Additionally, his fastball is almost fastest and has exceptionally high spin rate (Fig. 2), which would produce more lift force. Actually, he led his collegiate league in strikeouts per 9 innings, and batters facing him described his fastball as having good hop.

PRODUCTION OF BALL SPIN WITH FINGER MOVEMENT: In a recent study, we were able to analyze detailed motions of the fingers just before the release of a fastball (Fig. 4). The ball and the hand rotated together as one unit in the top-spin direction and the orientation of the ball relative to the hand did not change until the thumb slipped off the seam of the ball. This occurred approximately 6 ms before release. At this instant the ball started to rotate in the opposite direction (back spin). The duration of time required to produce back spin was, thus, remarkably short as compared to the duration of the acceleration phase which has been reported to involve 30-50 ms before release (Fleisig et al., 1999; Werner et al., 2008). The angle at which the fingertips reached forward over the ball during the top-spin phase was highly correlated with ball spin rate. In other words, ball spin rate was greater for the pitchers whose palm was facing more downward at the initiation of the back-spin phase. From this result, the importance of and kinematic mechanism for the link between ball speed and ball spin rate (Fig. 2) may be described as follows: First, accuracy is an essential requirement for pitching. Therefore, the vertical projection angle of the ball must be adjusted precisely for a given ball speed. The greater the ball speed, the more downward it must travel. To accomplish this, pitchers with a faster speed would need to hold the ball longer, which means that the palm would have to face more downward at the initiation of the back-spin phase. This would result in a longer period for acceleration to produce spin, and thus produce a higher ball spin rate.

Figure 4. Motion of the hand and ball as viewed from the side for 6 ms intervals from -42 ms (beginning of acceleration phase) to 6 ms. Note that the ball has “top-spin” until 6 ms before the release, from when it rotates with “back spin”. Crosses depict the center of the ball, and open circles denote the midpoint of index and middle finger tips.

EFFECS OF BALL SPIN ON BATTERS’ PERFORMANCE: We recently examined baseball batters’ accuracy in hitting fastballs with different backspin rates (30, 40, 50 rps) at a constant ball velocity (36 m/s) and with a constant orientation of the spin axis (straight back spin) (Higuchi et al., 2012). We found that ball spin rate was positively correlated with increases in the distance from the optimal contact point of the swung bat (sweet spot) to the actual point of contact (Fig. 5). That is, batters tended to hit under balls with a high spin rate, even at a constant ball velocity. One explanation for this result is based on the positive correlation between launched velocity and ball spin rate that exists for pitches thrown by real pitchers (Fig. 2). This correlation may allow batters to estimate spin rate from their judgment of a launched ball's velocity. Since the typical spin rate is around 30 rps for a 36 m/s fastball, this is likely the spin rate that the batters assumed was occurring for the pitches. Indeed, at 30 rps balls were mostly hit near the sweet spot. However, this expectation would cause a misestimate of the trajectory of this experiment's fastballs that had backspin rates other than 30 rps. This result and the performance of the collegiate pitcher described above (Sub. C in Fig. 2) suggest that throwing pitches with abnormal ball spin rates and/or unique spin axes makes pitches more difficult to hit.

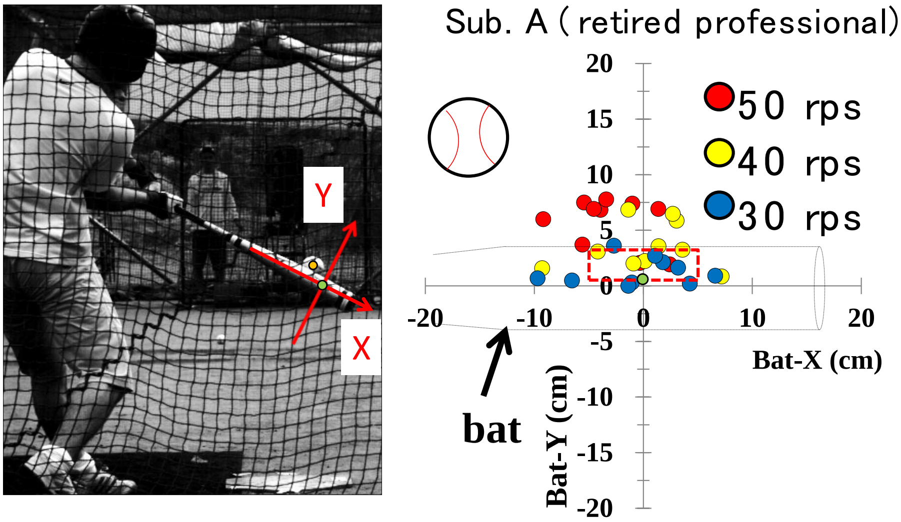

Figure 5. Definition of bat coordination and impact locations for a batter hitting pitches with three different back spin rates. Ball velocity was constant at 130 km/hr.

FUNCTION OF THE FASTBALL: The four-seam fastball focused on here is used by pitchers to overpower hitters, primarily because of the high velocity. The faster the pitch, the more effective it will be. From a certain point in a pitch's trajectory, batters actually can no longer react (owing to the time necessary to process the information and initiate the swing) and must make a decision whether, and how, to swing at the ball. Thus, they have to form a mental prediction of where the ball will subsequently travel. This gives them a chance to have the swinging bat at the right place at the right time. It requires many, many hours of practice to acquire this predictive ability. However, it is very difficult to tailor the long practice sessions to match the delivery patterns of individual pitchers. As a result, the trajectory the batters learn to expect is probably one for the "average pitcher". Thus, batters probably adopt the trajectory of the average speed and spin in establishing their "prediction" (Fig. 5).

Conversely, the pitcher who can throw a pitch whose trajectory deviates from the average batter's "prediction" will be at a clear advantage. There are two ways to gain this edge. The first is to throw a ball of extraordinarily high speed. The rationale in this case is to deliver a ball that passes through the batter's information processing window before the batter has time to process how fast the pitch is moving and where it will be when the ball is in the impact area. The second possibility is to deliver a ball with an unusual spin. Even if the speed is within the average range, a ball with a spin that deviates to a large degree from that of the "average ball" will have a trajectory that is quite different from that of the batter's "prediction" and will often be mishit. The orientation of the spin axis should also be taken into account. Lift force (not necessarily in the vertical direction) produced by the ball's spin is maximum when the spin axis is perpendicular to the ball's translational movement. In addition, if the axis is horizontally oriented, the lift force becomes purely upward, making the ball appear to ‘‘hop’’ (rise), and if the axis is vertical, the lift force is purely sideways. Of course, a ball with such an extreme spin would be rare. However, there were indeed wide variations in spin rate and orientation of spin axis in the pitches of the pitchers that we monitored, and to a certain extent, these characteristics could be related to the pitchers’ overall performance.

CONCLUSION: Dexterous manipulation of ball spin rates and ball spin axis, which determine the direction and magnitude of the drag force and lift force, are critical elements that allow pitchers to achieve a superior level of performance. Batters thus must take into account both ball spin rate as well as ball speed in order to optimize the ball-bat contact location.

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