SPIN OF A BATTED BALL TOWARD THE OPPOSITE FIELD IN BASEBALL

Hirotaka Nakashima[1], Yoshitaka Morishita[2], Kentaro Yagi[3] and Shinji Sakurai[4]

Graduate School of Health and Sport Sciences, Chukyo University, Toyota, Japan[1]
Department of Sports Science, Japan Institute of Sport Science, Tokyo, Japan[2]
Graduate School of Science Technology, Keio University, Yokohama, Japan[3]
School of Health and Sport Sciences, Chukyo University, Toyota, Japan[4]

The purpose of this study was to investigate the spinning motion of a ball batted toward the opposite field in baseball. A pitching machine was used to launch the balls toward the bat, which was adjusted and tied up to hit the balls in the opposite field. The ball movements were recorded using three high-speed video cameras. The results indicated that the batted ball backspin and sidespin components correlate strongly with the launch elevation angles and launch horizontal angles, respectively. All the batted balls had a certain amount of sidespin components. The balls batted toward the opposite field experienced unavoidable horizontal Magnus force, resulting in curving. Thus, it is important to launch the balls with a larger velocity to hit a long ball toward the opposite field while comparing with the balls batted towards the same field with less sidespin components.

KEYWORDS: spin axis, batted ball direction, sidespin, backspin.

INTRODUCTION: In baseball, making a long hit, such as a home run, is one of the most sought-after abilities in the sports. The most important factor that determines the ball flight distance is the batted ball velocity. Nathan (2008) reported that increasing the backspin rate resulted in an increase in flight distance for a given velocity and launch angle. Therefore, the effect of the batted ball spin on the flight distance cannot be neglected. Nakashima et al. (2018) compared the actual batted balls and its three-dimensional spin when it was toward the same field, center field, and opposite field. Results showed that there was no significant difference in the initial velocities and launch elevation angles of the batted balls among the three hitting directions. However, the flight distance for the opposite field was significantly shorter. This is due to the batted ball having a greater magnitude of the sidespin, experiencing a larger horizontal Magnus force, and relatively more sideway-curved trajectories. Thus, batters are suggested to give the ball backspin components rather than sidespin components, along with high velocities to hit a long ball toward the opposite field.
In a previous study, Nathan et al. (2012) investigated the ball spin after its impact with the stationary cylinder. This revealed that increasing the launch elevation angles of the batted balls results in an increase of the backspin rate. This study led to understanding the optimal launch elevation angles need to hit a long ball. However, this study only focused on the balls batted toward the center field describing only the backspin and topspin. For balls batted toward the opposite field with a larger sidespin magnitude, the three-dimensional ball spin should be considered. This will be relevant to hit a long ball and reveal the ball spin changes with increasing launch elevation angles of balls batted toward the opposite-field.
The purpose of this study was to investigate the spin of a batted ball after impact with a bat angled to simulate hits to the opposite field.

METHODS: The experiment was conducted in an indoor baseball practice area. An air-shoot pitching machine (TOPGUN, Kyowagiken Inc.) launched the balls toward the tied up wooden bat. The long axis of the bat was adjusted horizontally by 15° towards the opposite field. The pitching machine was placed 2 m in front of the bat. To simulate the actual relative velocity during the bat-ball impact, the pitched ball velocity was set to approximately 85 m/s. The spin of the pitched ball was adjusted to approximately 20 rps with backspin. Figure 1 shows the experimental set-up.

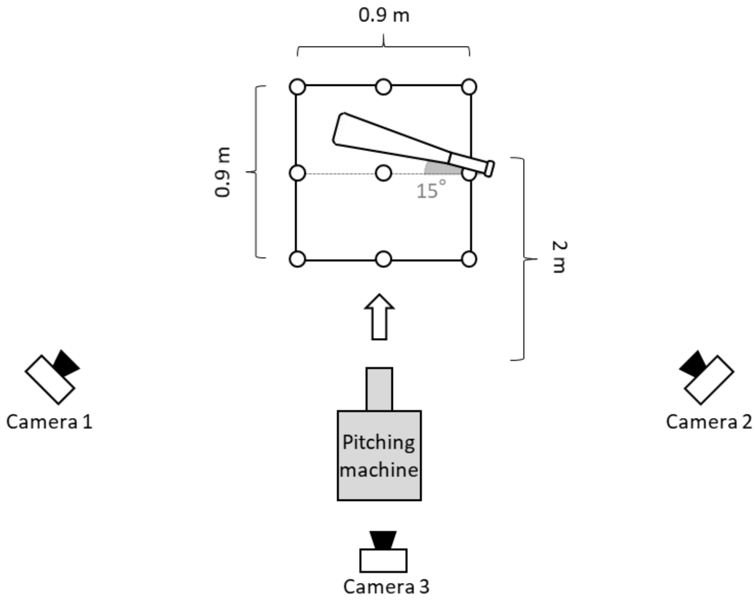

Figure 1 Experimental set-up (top view).

The ball movements were recorded with three high-speed video cameras with a frame rate of 1000 fps and exposure time of 1/10000 sec (MEMRECAM HX-7S and MEMRECAM MX, NAC Image Technology Inc.). Camera 1 and Camera 2 were used to calculate the batted ball launch angles. Three-dimensional coordinates of the ball centers were acquired using direct linear transformation (DLT) methods. The calibration errors of x, y, and z were 1 mm, 1 mm, and 2 mm, respectively. The batted ball launch elevation angle was defined as the angle between the batted ball initial velocity vector and horizontal plane. On the other hand, the batted ball launch horizontal angle was defined as the angle between the batted ball initial velocity vector in the horizontal plane and the vector opposite to the direction of the pitched ball's pre-impact velocity in the horizontal plane. Camera 3 was used to calculate the batted ball angular velocity vector using the methods of Jinji and Sakurai (2006). The coordinate system was constructed with Y as the batted ball initial velocity vector, X as orthogonal with Y and the vertical direction, and Z as the cross product of X and Y. The spin axis angles α, θ, and ϕ were defined as the angles between the spin axis vector and Y, spin axis vector in the X-Y plane and X, and spin axis vector and the X-Y plane, respectively (Figure 2a). The spin rate and the three components of backspin (x), spiralspin (y), and sidespin (z) were defined as the spin rotation per second (Figure 2b).

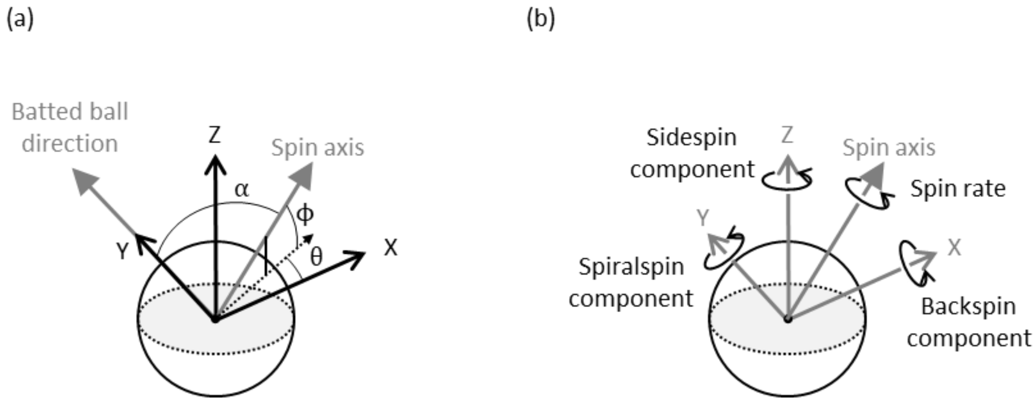

Figure 2 Definition of (a) angle of spin axis and (b) spin rate and the components.

Pearson's correlation was used to quantify the relationships between the batted ball launch elevation angles and the spin parameters. The significance level was set at $p < 0.05$.

RESULTS: Twenty trials, in which the marks on the ball were clearly visible for digitization, were analyzed. The mean launch elevation and horizontal angle was 35.6±15.2°, and 68.0±10.4°, respectively. The range of the batted ball launch elevation angles was from 10.2 to 61.5°. There were significant correlations between the launch elevation angles and spin rate ($r = 0.702$, $p < 0.01$, Figure 3a), between the launch elevation angles and spin axis angle ϕ, ($r = 0.934$, $p < 0.01$, Figure 3b), between the launch elevation angles and backspin component ($r = 0.472$, $p < 0.05$, Figure 3c), and between the launch elevation angles and sidespin component ($r = -0.563$, $p < 0.01$, Figure 3d). Whereas, there were no significant correlations between the launch elevation angles and the other spin parameters. However, there was significant correlation between the launch elevation angle and the launch horizontal angle ($r = -0.610$, $p < 0.01$). Nakashima et al. (2018) reported that the sidespin is strongly correlated with the launch horizontal angles. Therefore, partial correlation analysis was used to investigate the relationship between the launch elevation angle and the spin parameters without the influence of the launch horizontal angle. Table 1 lists the partial correlation coefficients.

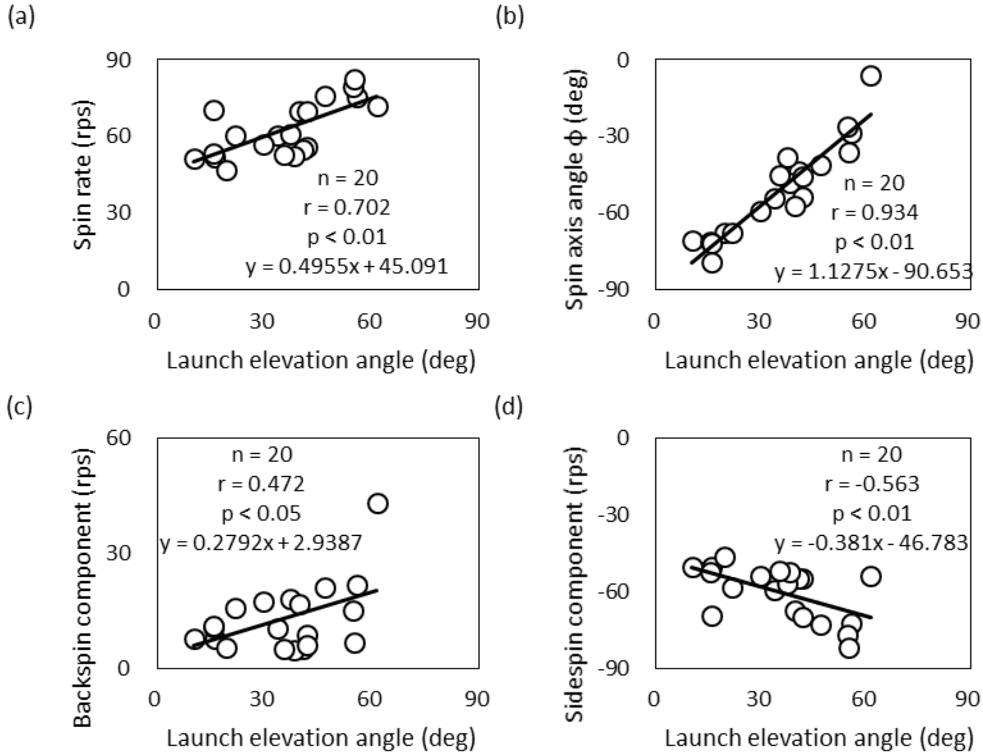

Figure 3 Relationships between the batted ball launch elevation angle and (a) the spin rate, (b) the spin axis angle ϕ, (c) the backspin component, and (d) the sidespin component.

Table 1 Partial correlation coefficients between the launch vertical angle and the spin parameters.

control variable	Spin rate	Backspin	Sidespin	ϕ
Launch horizontal angle	.640 **	.866**	-0.38 (n.s.)	0.907 **

Note: *: p <0.05, **: p <0.01, n.s.: non-significant.

DISCUSSION: The purpose of this study was to investigate the batted ball spin after it impacts the bat adjusted to hit the balls to the opposite field. From the results, the increase in launch elevation angles resulted in an increase in the backspin component. This result was similar to that of Nathan et al. (2012). It was considered that the lower the impact on the ball the higher the launch elevation angle and amount of backspin. In addition, an increase in the launch elevation angles results in an increase in the sidespin component. However, the launch horizontal angle also increases. Nakashima et al. (2018) reported that the sidespin is strongly correlated with the launch horizontal angles. Therefore, partial correlation analysis was performed to avoid the influence of the launch horizontal angle. As a result, there was no significant partial correlation between the launch elevation angle and the sidespin component. This result indicates that the increase in launch elevation angles did not result in an increase in the sidespin component. It also supported the study of Nakashima et al. (2018) which reported the significant correlation between the launch horizontal angle and sidespin component. Considerably, the batted ball backspin and sidespin components strongly correlates to the launch elevation angles and launch horizontal angles, respectively.
In this study, all the batted balls had a certain amount of sidespin components. Thus, it is unavoidable for the balls batted toward the opposite field to experience the horizontal Magnus force and be curved sideways. Therefore, it is important for batters to deliver the ball with a greater velocity to hit a long ball toward the opposite field while comparing with the balls batted toward the same field with less sidespin components.
However, this study still possesses limitations. Although the bat head was usually lower than the bat grip during impact, the bat was only adjusted in the horizontal plane. The bat angle along the vertical plane also affected the batted balls. Therefore, future works should focus on the investigation of the batted ball spin after bat impact adjusted in both the horizontal plane and vertical plane.

CONCLUSION: This study indicated the batted ball backspin and sidespin components strongly correlates to the launch elevation angles and launch horizontal angles, respectively. All the batted balls in this study had a certain amount of the sidespin components. It is inevitable for balls batted toward the opposite field to experience the horizontal Magnus force resulting in sideways curving. Therefore, it is important for batters to deliver the ball with a greater velocity to hit a long ball toward the opposite field while comparing with the balls batted toward the same field with less sidespin components.

REFERENCES

Jinji, T., & Sakurai, S. (2006). Direction of spin axis and spin rate of the pitched baseball. *Sports Biomechanics*, 5(2), 197-214.

Nakashima, H., Horiuchi, G., & Sakurai, S. (2018). Three-dimensional batted ball in baseball: effect of ball spin on the flight distance. *Sports Engineering*, 21,493-499.

Nathan, A. M. (2008). The effect of spin on the flight of a baseball. *American Journal of Physics*, 76(2), 119-124.

Nathan, A. M., Cantakos, J., Kesman, R., Mathew, B., & Lukash, W. (2012) Spin of a batted baseball. *Procedia Engineering*, 34, 182-187.

ACKNOWLEDGEMENTS: This study was conducted as collaborative research with the Japan Institute of Sports Sciences. The authors also thanks NAC Image Technology Inc. for providing three high-speed high-resolution video cameras, Kyowagiken Inc. for providing the air-shoot pitching machine for the ultrahigh-speed ball launch, and Editage (www.editage.jp) for English language editing.