KINEMATIC ANALYSIS OF BASEBALL BATTING MOTION WHEN BATTING PITCHES WITH VARYING VELOCITIES

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The purpose of this study was to identify effect of moving the center of gravity of the body and rotating the torso when batting pitches with varying velocity. The subjects were 10 experienced university baseball player. The subjects batted toward the center field, both fastballs and slowballs, aimed near the center of the strike zone from a pitching machine. Data were collected using a three dimensional automatic motion analysis system (Vicon MX). The rotation angle of the torso and displacement of the center of gravity were computed. Due to differences in the shoulder rotation from the latter half of stepping leg touchdown through impact, we believe that the motion is adapted to pitch differences starting from the latter half of stepping leg touchdown. Comparing the shift in the center of gravity of the body during fastballs and slowballs, the forward motion and downward sinking of the center of gravity were significantly larger for slowballs.

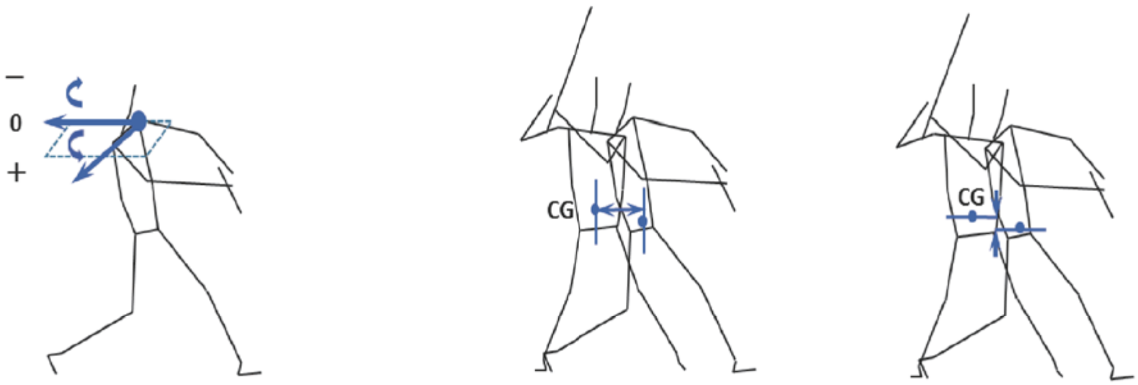
KEY WORDS: motion analysis, center of gravity, rotation of the torso.

INTRODUCTION: Previous studies on baseball batting motion were primarily concerned with tee batting (Tago et al., 2006; Escamilla et al., 2009) or batting fastballs pitched near the center of the strike zone (McIntyre and Pfautsch, 1982; Messier and Owen, 1985). In real games, it is inconceivable that the pitcher would only pitch fastballs or balls following identical courses; therefore, it is considered an important task for a batter to respond appropriately to various pitch velocities and trajectories. In this context, the movement of the center of gravity of the body and the rotation of the torso are considered extremely important actions for gathering speed during batting motion. Thus, this study focused on differences in pitching speed with the objective of garnering fundamental knowledge useful for improving batting techniques by kinematically analyzing the effect of moving the center of gravity of the body and rotating the torso when batting pitches with varying velocity.

METHODS: The subjects were 10 experienced university hardball team members (height: 1.75±0.03 m; weight: 75.3±3.8 kg; competitive experience: 11.4±2.5 years; all right-hitting) selected on the basis of instructor evaluations.

The subjects batted, toward the center field, both fastballs (approximately 125 km/h) and slowballs (corresponding to curveballs at approximately 90 km/h), aimed near the center of the strike zone from a pitching machine placed 17.0 m away. Speed of the pitching machine was a speed that is set in the daily practice. To approximate real game circumstances, the pitching sequence of fastballs and slowballs was set randomly, and the batting was conducted with the batter being unaware of what type of pitch would be thrown. Each subject batted 7-8 instances of each pitch type.

To achieve a same batting direction, a net 4.0 m tall and 4.0 m wide was prepared 2.0 m above the ground at a location 20 m away from the batter in the direction of the center field. Of the balls that were caught in the net, the attempt exhibiting the fastest batted ball speed



Rotation angle of the shoulders and hips

CG movement of the Y-axis direction

CG movement of the Z-axis direction

Figure 1 Definition of calculated data

was used in the analysis.

A total of 51 reflective markers (47 on the body of the subject and 4 on the bat) were affixed, and the three-dimensional coordinates of each marker were measured using an optical three-dimensional automatic motion analysis device (Vicon Motion Systems Ltd. UK, Vicon MX, with 12 cameras and a 250 Hz sampling frequency).

In this study, the batting motion at three events in time was the subjects of analysis: stepping leg liftoff, stepping leg touchdown, and impact. In this study, we set a global coordinate system with the Y-axis being a vector from the home plate towards the pitching machine, the X-axis being a vector perpendicular to the Y-axis from the right batter's box to the left batter's box, and the Z-axis being a vertical line. The shift in the center of gravity of the body with respect to the Y- and Z-axes and the rotational angle of the torso (shoulders and hips) projected onto the XY plane from the obtained three-dimensional coordinate values were calculated (Figure 1).

The data is presented as means. An unpaired t-test was used to test for statistical differences in distributed data of the two ball speed groups. Statistical significance level set at $P < 0.05$. Statistical analysis were performed using the SPSS Statistics 15.0 (SPSS Inc., Chicago, IL).

RESULTS: In relation to ball release time by pitching machine, the fast ball had an average of -0.48s and the slow ball had an average of -0.67s. Impact point set to 0s.

Table 1 indicates the shoulder rotation angles for each pitching velocity. The rotation angle

Table 1 Rotation angle of the shoulders

	Step leg liftoff	Step leg touchdown	Impact
Fast ball	-10.4	-24.8	71.2
Slow ball	-11.5	-21.1	80.3 *

unit : deg

* <0.05

Table 2 Rotation angle of the hips

	Step leg liftoff	Step leg touchdown	Impact
Fast ball	-11.8	-22.1	58.2
Slow ball	-16.1	-20.9	56.7

unit : deg

was defined as the angle formed by a vector from the left shoulder to the right shoulder and a Y-axis vector in the negative direction with respect to the global coordinate system, and a rotation in the direction of the pitcher was considered the positive (+) direction (Figure 1). No difference in shoulder rotation was seen between the fastballs and slowballs at the times of stepping leg liftoff or stepping leg touchdown. We observed a difference at the time of impact, with a significantly larger shoulder rotation in the batting direction for fastballs than for slowballs.

Table 2 indicates hip rotation angles, similar to the shoulder rotation angles. No statistically significant difference in hip rotation was seen between the fastballs and slowballs at any of the action points.

Table 3 indicates the shift in the center of gravity of the body in the Y-axis direction (direction of the machine) with pitching speed. This was calculated by projecting the coordinates of the center of gravity onto the global coordinate system set in this experiment. No difference was seen in the shift in the Y-axis direction between the fastballs and slowballs at the times of stepping leg liftoff or stepping leg touchdown. A difference was seen at the time of impact, when the shift in the Y-axis direction was significantly greater for slowballs than for fastballs.

Table 4 indicates the shift in the center of gravity of the body in the Z-axis direction (vertical direction), similar to the Y-axis case. No difference was seen in the shift in the Z-axis direction between the fastballs and slowballs at the times of stepping leg liftoff or stepping leg touchdown. A difference was seen at the time of impact, when the shift in the Z-axis direction was significantly greater for slowballs than for fastballs.

Table 3 Displacement of the CG for Y axis

	Step leg liftoff	Step leg touchdown	Impact
Fast ball	0.59	0.68	0.86
Slow ball	0.58	0.70	0.89
			*

unit : m

* <0.05

Table 4 Displacement of the CG for Z axis

	Step leg liftoff	Step leg touchdown	Impact
Fast ball	0.96	0.94	0.91
Slow ball	0.95	0.93	0.87
			*

unit : m

* <0.05

DISCUSSION: By investigating the motion of rotating the torso from take-back to impact, we revealed that the shoulder rotated at nearly the same angle until the middle of stepping leg touchdown regardless of pitch type. Due to differences in the rotation angle from the latter half of stepping leg touchdown through impact, we believe that the motion is adapted to pitch differences starting from the latter half of stepping leg touchdown.

Furthermore, when the batters recognized a curveball, they moved by intentionally rotating the shoulder to strike at a point closer to the pitcher compared to fastballs, reflecting the technical advice to “strike at the beginning of the pitched ball’s curve” for hitting slowballs (corresponding to curveballs). This suggests that the results of this study can support the real-world instruction method that is based on experience.

Further, the fact that no difference could be seen between pitch types at any event when rotating the hips, suggests that rather than adjusting hip rotation according to differences in pitch types, it is preferable to adjust the rotation of the shoulders and the style of moving the body.

Comparing the shift in the center of gravity of the body during fastballs and slowballs, the forward motion and downward sinking of the center of gravity were significantly larger for slowballs. Impacting close to a direct collision is said to be desirable to achieve impact speed when batting in baseball. Thus, we believe that the center of gravity may have been lowered somewhat for slowballs because of a need to impact the bat from slightly below to approach a direct collision since slowballs have a greater downward movement than fastballs.

The center of gravity also shifted more in the Y-axis direction for slowballs than for fastballs. This is a manifestation of the motion of "going to meet the ball," and is considered a factor preventing a proper swing. In this study, batting was performed under conditions of an unknown pitching speed. In this context, we infer that the more frequent motion of "going to meet the ball" among the slowballs is due to the difficulty in correcting this excess body movement in the Y-axis direction during one's own batting motion. The excess body movement in the Y-axis direction appeared inevitably when slowballs arrived amidst unpredictable pitching, and so, rather than coaching to suppress excess movement, we believe that it is preferable for coaching to take into consideration how to effectively strike slowballs in spite of the movement.

CONCLUSION: The purpose of this study was to identify effect of moving the center of gravity of the body and rotating the torso when batting pitches with varying velocity.

Due to differences in the shoulder rotation from the latter half of stepping leg touchdown through impact, we believe that the motion is adapted to pitch differences starting from the latter half of stepping leg touchdown.

The excess body movement in the Y-axis direction appeared inevitably when slowballs arrived amidst unpredictable pitching, and so, rather than coaching to suppress excess movement, we believe that it is preferable for coaching to take into consideration how to effectively strike slowballs in spite of the movement.

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