INFLUENCE OF THE BALL SPEED ON THE DISPLACEMENT OF THE CENTER OF GRAVITY DURING BASEBALL BATTING MOTION

Takahito Tago[1], Kenichi Kaneko[1], Daisuke Tsuchioka[1], Nobuko Ishii[1], Tadashi Wada[2]
Tokushima Bunri University, Tokushima, Japan[1]
Kokushikan University, Tokyo, Japan[2]

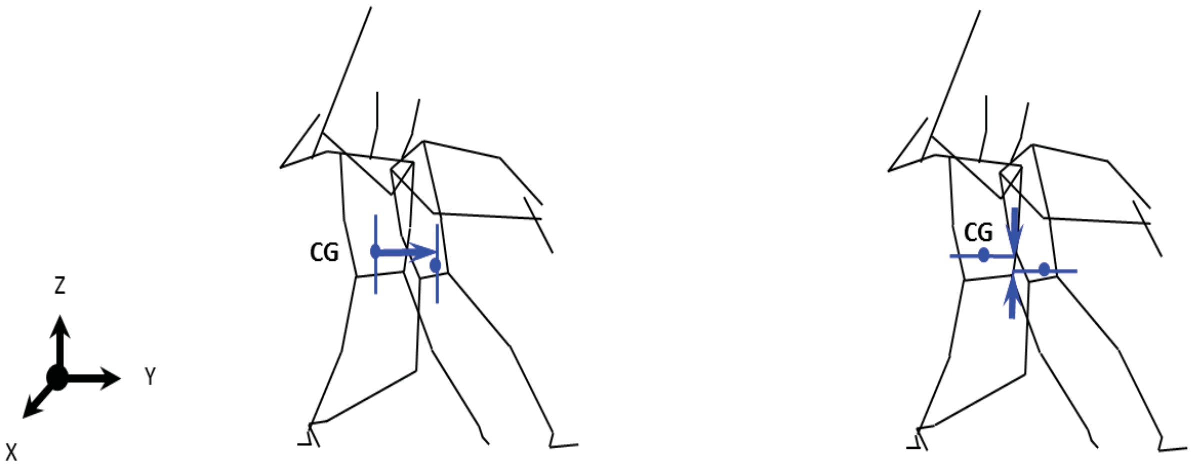
The purpose of this study was to investigate the modification in batting motion with different pitching speeds focusing on differences in batting technical level. The subjects were 10 experienced university baseball player. The subjects batted toward the center field, both fastballs and slowballs, aimed 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 displacement of the center of gravity(CG) were computed. Significant differences were seen due to difference in pitching speed in unskilled player. Conversely, in skilled player, no significant difference was found in the movement of CG due to the difference in pitching speed. It was revealed that it was not preferable for movement of the CG to fluctuate by difference in pitching speeds.

KEY WORDS: motion analysis, center of gravity, fast ball, slow ball.

INTRODUCTION: Pitchers in the actual game are not expected to pitch all the balls at the same speed and responding appropriately to various ball speeds and hitting accordingly is considered an important task for the batter. So far, much of the research done so far on the hitting motion of baseball is related to tee batting (Tago et al., 2006; Escamilla et al., 2009) or hit against fast balls pitched near the center of the strike zone (McIntyre and Pfautsch, 1982; Messier and Owen, 1985). However, in actual game, it is unlikely that only balls of the same ball speed get pitched and it is considered an important task for batters to appropriately respond to various ball speeds and hit them. In order to obtain the hitting speed, batters tried to effectively utilize the movement of the body and therefore investigated the movement style of the center of gravity. Accordingly, in this study, focusing on the difference in pitching speed, we have aimed to analyze the modification in batting behavior owing to the difference in ball speed and to obtain basic knowledge that will help in improving batting technique through an understanding of the difference.

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 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: step leg liftoff, step 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 from the obtained three-dimensional coordinate values were calculated (Figure 1).

The data is presented as means. An paired 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).



CG movement of the Y-axis direction

CG movement of the Z-axis direction

Figure 1. Definition of calculated data

RESULTS: Tago et al.,(2016) reported that there was a significant difference only at the time of impact, when the shift in the Y-axis direction was significantly greater for slowballs than for fastballs and the shift in the Z-axis direction was significantly greater for slowballs than for fastballs in the average of 10 subjects. This suggests that the aspect of body displacement is similar in the case of the fast ball and slow ball. To verify this in further detail, we selected the top 3 and the bottom 3 batters from among the fast hitters of the batted ball speed (skilled player) and the slow hitters of the batted ball speed (unskilled player) for comparison.
Table 1 indicates the shift in the center of gravity of the body in the Y-axis direction (direction of the machine) with different pitching speed in the skilled player. This was calculated by projecting the coordinates of the center of gravity onto the global coordinate system set in this experiment. No significant difference was seen in the shift in the Y-axis direction between the fastballs and slowballs at the time of all events.
Table 2 indicates the shift in the center of gravity of the body in the Y-axis direction (direction of the machine) with different pitching speed in the unskilled player. No significant difference was seen in the shift in the Y-axis direction between the fastballs and slowballs at the times of

Table 1. Displacement of the CG for Y axis in the skilled player (M±SD).

	Step leg liftoff	Step leg touchdown	Impact
Fast ball	0.61±0.06	0.68±0.05	0.86±0.04
Slow ball	0.60±0.10	0.70±0.07	0.89±0.07

Note: unit : m

Table 2. Displacement of the CG for Y axis in the unskilled player (M±SD).

	Step leg liftoff	Step leg touchdown	Impact
Fast ball	0.62±0.07	0.71±0.06	0.85±0.05
Slow ball	0.61±0.09	0.76±0.07 ※	0.94±0.07 ※

Note: unit : m
※$p < 0.05$

step leg liftoff. A difference was seen at the time of step leg touchdown and impact, when the shift in the Y-axis direction was significantly greater for slowballs than for fastballs.

Table 3 indicates the shift in the center of gravity of the body in the Z-axis direction (vertical direction) with different pitching speed in the skilled player, similar to the Y-axis case. No significant difference was seen in the shift in the Z-axis direction between the fastballs and slowballs at the times of all events.

Table 4 indicates the shift in the center of gravity of the body in the Z-axis direction (vertical direction) with different pitching speed in the unskilled player. No significant difference was seen in the shift in the Z-axis direction between the fastballs and slowballs at the times of step leg liftoff. A difference was seen at the time of step leg touchdown and impact, when the shift in the Z-axis direction was significantly greater for slowballs than for fastballs.

Table 3. Displacement of the CG for Z axis in the skilled player (M±SD).

	Step leg liftoff	Step leg touchdown	Impact
Fast ball	0.93±0.06	0.94±0.07	0.92±0.05
Slow ball	0.94±0.08	0.93±0.09	0.92±0.07

Note: unit : m

Table 4. Displacement of the CG for Z axis in the unskilled player (M±SD).

	Step leg liftoff	Step leg touchdown	Impact
Fast ball	0.94±0.09	0.91±0.07	0.86±0.06
Slow ball	0.93±0.09	0.89±0.08	0.85±0.07
		※	※

Note: unit : m

※$p < 0.05$

DISCUSSION: The statistical difference was not seen between both speeds and both groups about the appearance time of each event. This suggests that it is important to consider how to displace the body more than the appearance time of each event when hitting a fast and slowball.

The comparison of the movements of the fast and slow balls shows that in both groups, the forward and downward shift of the center of gravity of the body was larger in the slow ball. In order to acquire the ball speed in baseball batting, it is said to be desirable to have an impact as close to direct collision (The relative velocity vector between the colliding objects and the impact line are on the same line) as possible. Since the movement of the ball in the downward direction is larger in the slow ball than in the fast ball, it is necessary to impact the bat from a slightly lower position than in the fast ball delivery to be able to approach the state of direct collision and hence it might be better to lower the center of gravity. Further, the displacement of the center of gravity of the body in the machine direction was greater in the slow ball than at the time of fast ball in the unskilled player. For this reason, it is considered important to suppress, to the extent possible, the action of the so-called “go to meet the ball” when hitting the slow ball, as far as the unskilled player is concerned.

CONCLUSION: In the skilled player, no significant difference was seen in the shift in the Y and Z-axis direction between the fastballs and slowballs at the time of all events. In the unskilled player, a difference was seen at the time of step leg touchdown and impact, when the shift in the Y and Z-axis direction was significantly greater for slowballs than for fastballs. It was revealed that quantity of body movement changed between types of pitches by the difference in batting technique level.

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