ADJUSTMENT MOVEMENT OF CENTRE OF GRAVITY TO BASEBALLS TOSSED AT DIFFERENT VELOCITIES IN BASEBALL BATTING.

Takahito Tago, Kenichi Kaneko, Daisuke Tsuchioka and Nobuko Ishi

Tokushima Bunri University, Tokushima, Japan

This study compared shifts in the centre of gravity (CG) when balls were tossed at different velocities, in order to obtain data for coaching purposes. The subjects were 10 experienced university baseball players. The subject batted basic toss-up ball toward the centre field, both fastballs and slowballs. Data were collected using 2 high-speed cameras (NAC Inc., Japan). The movement timing and velocity of the center of gravity were computed. Batting motion was divided into three phases. The mean times in the 1st phase and 3rd phase were approximately the same for both fast and slow balls, but both the time and distance by which the CG moved in the 2nd phase were significantly greater for slow balls than for fast balls.

KEY WORDS: kinematics, hitting, toss up, fast ball, slow ball.

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). Batting movements in response to baseballs pitched at different velocities have been studied from the perspective of ground reaction forces and timing of the stepping leg, but no study has addressed the question of a shift in the centre of gravity (CG), which is fundamental to body movement. However, a recent increase in the use of change-up pitches suggests that the identification of movements used to adapt to different ball velocities would provide useful information for coaches. We used the basic toss hit to compare shifts in the CG when balls were tossed at different velocities, to obtain data for use in coaching.

METHODS: The subjects were 10 experienced university baseball team members (height: 1.76±0.04 m; mass: 74.6±4.1 kg; competitive experience: 10.8±3.3 years; all right-hitting) selected on the basis of instructor evaluations.
All batting motions used in the present study were those normally used in the competitive field. The order of the trials for each toss up ball were determined randomly. For each trial, they were asked to take a moment to formulate a 5-point assessment (5, very good; 3, normal; 1, very bad) that comprehensively took into account the intensity and direction of the ball. The trials that received the highest assessment scores were subject to further analysis.
An imaging area 3.0 m in the right-left direction (X-axis), 4.0 m in the direction of the centre field (Y-axis), and 2.5 m high (Z-axis) was established, and 2 high-speed cameras (HSV-500C^3, NAC Inc., Tokyo, Japan) were used for front and side imaging of the trials. The experimental trials were videotaped at a frame rate of 250 Hz and an exposure time of 1/1,000 s.
To assist with the analysis, batting motion was divided into three phases (Figure 1). These were: the 1st phase of toe on (T-on) from the foot off (F-off), the 2nd phase of heel on (H-on) from T-on, and the 3rd phase of the ball impact (IMP) from H-on.
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 (Fastball and Slowball). Statistical significance level set at $p < 0.05$. Statistical analysis were performed using the SPSS Statistics 15.0 (SPSS Inc., Chicago, IL).

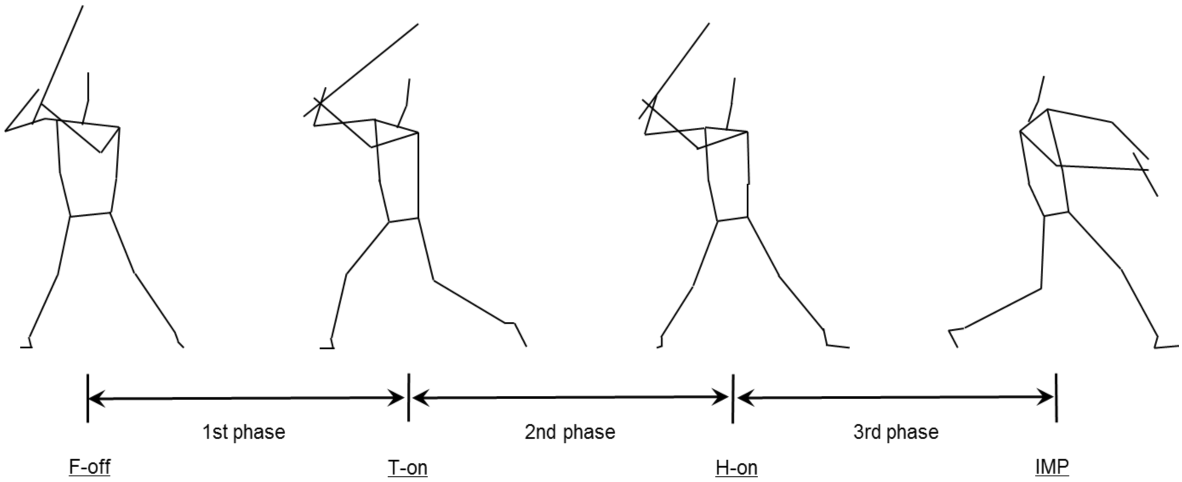

Figure 1. Definition of the movement

RESULTS: Table 1 shows the duration from ball release to T-on and the toss time. There was no significant difference in the duration for slow and fast balls. The toss time was significantly longer for slow balls than for fast balls. The difference between

Table 1. Time from ball release time to T-on time and toss time

Subjects	Rel～T-on		Toss time = Rel～Imp	
	FB	SB	FB	SB
A	0.31	0.38	0.51	0.70
B	0.30	0.27	0.53	0.70
C	0.37	0.34	0.59	0.70
D	0.28	0.28	0.57	0.74
E	0.11	0.13	0.51	0.68
F	0.28	0.27	0.54	0.71
G	0.26	0.29	0.57	0.71
H	0.28	0.27	0.54	0.72
I	-0.09	-0.07	0.56	0.71
J	0.38	0.25	0.56	0.70
Mean±SD	0.25±0.14	0.24±0.13	0.55±0.03＊	0.71±0.01＊

＊: Significant at the $p < 0.05$ level.

FB: Fast ball, SB: Slow ball, T-on: Toe contact, IMP: Impact, Rel: Ball release.

Unit: s

the two toss types was 0.16 s. Table 2 shows the timing of each stage. There was no significant difference between the timing of the 1st phase and 3rd phase for the two ball velocities. The timing of the 2nd phase was significantly longer for slow balls than for fast balls.

Figure 2 shows the Y-axis component of the CG velocity. For fast balls, the velocity of the CG gradually increased from T-on and peaked at H-on. For slow balls, the velocity exhibited a double peak at close to T-on and close to H-on.

	1st phase		2nd phase		3rd phase	
	Mean	SD	Mean	SD	Mean	SD
FB	0.54	0.21	0.16	0.14	0.14	0.02
SB	0.51	0.21	0.31	0.12	0.15	0.02
			∗			

∗ : Significant at the 0.05 level.
FB: Fast ball, SB: Slow ball
Unit: s

Table 2. Time of each movement phase

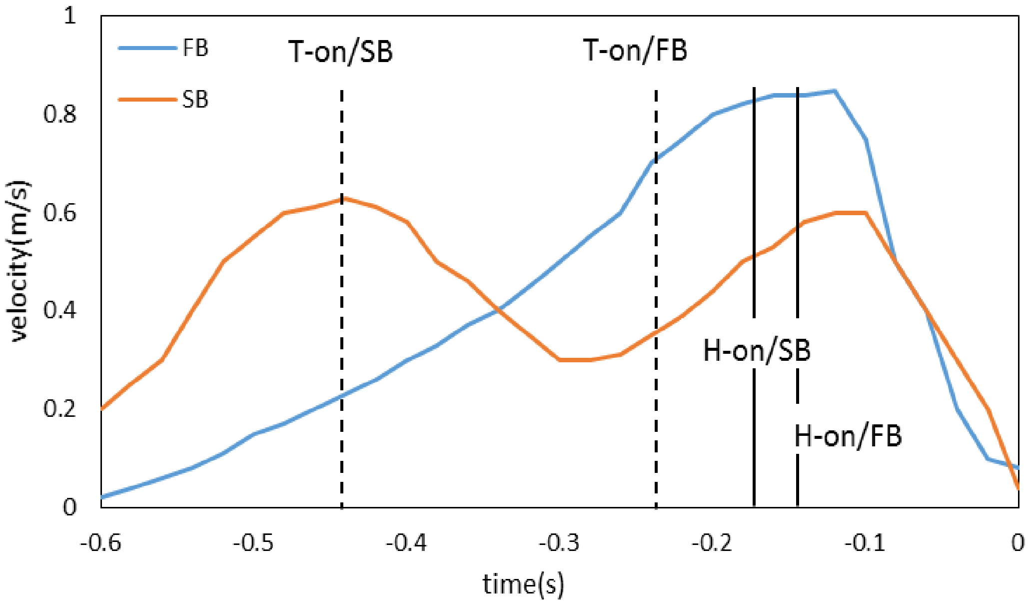

Figure 2. Movement velocity of CG

DISCUSSION: For fast balls, the velocity of the CG gradually increased from T-on and peaked close to H-on. For slow balls, the velocity exhibited a double peak, with maximum values at close to T-on and close to H-on. This indicates that when the player was tossed a fast ball, the velocity of the CG increased smoothly until H-on. In contrast, when the player was tossed a slow ball, the velocity of the CG initially increased up to T-on to adjust to the time difference between a slow and fast ball, but decreased or was maintained in the 2nd phase before increasing to the same or faster velocity at H-on.

This suggested that limiting the velocity of the CG in the 2nd phase when facing a slow ball restricts the CG from shifting toward the batting direction. Subsequent to H-on, the velocity of the CG rapidly decreased for both fast and slow balls, and by Imp the velocity had diminished to almost 0 m/s, possibly because the kinetic chain resulted in conversion from translational motion to rotational motion.

The mean times in 1st phase and 3rd phase were approximately the same for both fast and slow balls, but both the time and distance by which the CG moved in the

2nd phase were significantly greater for slow balls than for fast balls. This indicated that timing adjustment mainly takes place during 2nd phase, and that the manner in which the CG shifts when facing slow balls is a time-dependent action.
These results suggested that adjusting the velocity of movement of the CG changes the timing of heel strike, that is, performing a time adjustment in the 2nd phase is important when dealing with variations in the velocity of tossed balls.

CONCLUSION: The mean times in 1st phase and 3rd phase were approximately the same for both fast and slow balls, but both the time and distance by which the CG moved in the 2nd phase were significantly greater for slow balls than for fast balls.
Timing adjustment to slow or fast balls in baseball batting mainly takes place during 2nd phase, and that the manner in which the CG shifts when facing slow balls is a time-dependent action.

REFERENCES

Escamilla R.F., Fleisig G.S., DeRenne C., Taylor M.K. (2009). Effects of Bat Grip on Baseball Hitting Kinematics. *J. Appl. Biomech*., 25, 203－209

McIntyre D.R., Pfautsch E.W. (1982). A kinematic analysis of the baseball batting swings involved in opposite-field and same-field hitting. *Res. Quart.*, 53, 206－213

Messier S.P., Owen M.G. (1985). The Mechanics of Batting: Analysis of Ground Reaction Forces and Selected Lower Extremity Kinematics. *Res. Quart.*, 56(2), 138－143

Tago T., Ae M., Fujii N., Koike S., Takahashi K., and Kawamura T. (2006). Effects of the height of hitting point on joint angular kinematics in baseball batting. *Japanese Journal of Biomechanics in Sport and Exercise*, 10(1), 2－13