A BIOMECHANICAL STUDY OF TIMING IN BASEBALL BATTING AGAINST A PITCHED FASTBALL: COMPARISON OF BATTING SITUATIONS WITH AND WITHOUT PRIOR KNOWLEDGE OF THE TYPE OF PITCH

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The aim of the study was to examine the differences in the timing of the batting motion between a situation in which the batter knew beforehand the type of incoming pitch and a situation in which he did not. Nine pitchers and 9 batters participated in this study. Batters were requested to hit the pitched ball in known-pitch and unknown-pitch situations. A successful trial of the batter was one in which the ball was hit squarely; a failed trial was one that produced a glancing blow. Pitching and batting motions were recorded with video cameras and a motion capture system. In the known-pitch situation, significant positive correlations were found between four batting phases and three pitching phases. The results suggested that the timing strategy of the batting motion in the unknown situation is different from that of the known situation.

KEY WORDS: kinematics, phase of motion, correlation, joint movement index, 3D analysis

INTRODUCTION: Previous biomechanical studies of baseball have investigated separately the pitching and hitting motions, and they have provided useful findings (Feltner & Dapena, 1986; Sakurai, Ikegami, Okamoto, Yabe & Toyoshima, 1993; Matsuo, Escamilla, Fleisig, Barrentine & Andrew, 2001; Fleisig, Barrentine, Zheng, Escamilla & Andrew, 1999; Escamilla, Fleisig, DeRennem, Taylor, Moorman, Imamura, Barakatt & Andrews, 2009a,b; Miyanishi, Sakurai & Endo, 2015a,b). However, an actual match-up between a pitcher and a batter forces the batter to predict what the pitcher is going to do before swinging the bat with correct timing to hit the ball successfully. There has never been a study that investigated the batting motion in an actual match-up against the pitcher. Thus, this study aimed to clarify how batters control their batting in response to pitching, by investigating the differences in the kinematics of batting between known and unknown pitch situations in terms of timing control.

METHODS: Nine male baseball pitchers (age, 19.3 ± 1.7 yrs; standing height, 1.73 ± 0.05 m; body mass, 72.9 ± 6.9 kg; pitching experience, 11.6 ± 2.2 yrs) and 9 batters (age, 19.9 ± 1.8 yrs; standing height, 1.73 ± 0.04 m; body mass, 75.5 ± 7.2 kg; batting experience, 11.7 ± 1.9 yrs) from high school and university baseball clubs participated in this study after giving informed consent. The experiment included two batting situations: known pitch and unknown pitch. In the known pitch situation (81 fastball pitches and 54 breaking ball pitches, 135 in total), the batter was told what type of pitch was going to be used (fastball or breaking ball, which in turn could be a curveball or a slider), while in the unknown pitch situation (124 fastball pitches and 61 breaking ball pitches, 185 in total) he was not told. For all trials, the pitching and batting motions were recorded, respectively, with two high-speed video cameras (HSV-500C^3, NAC, Japan) and a 9-camera motion capture system (VICON MX-T20, Vicon Motion Systems Ltd., UK), both operating at 250 Hz. In addition, the ground reaction forces of the pitcher and batter were simultaneously measured at 1000 Hz by four force platforms (pitcher: two of type 9281CA; batter: two of type 9287B, Kistler Co., Ltd., Japan). To estimate the instant of impact between bat and ball, the sound of the impact was recorded with a microphone placed on the ground, 2.6 m away from the home plate, and connected to the computer; an 8 ms adjustment was made to account for the time that it took for the sound to travel from the point of impact to the microphone. Trials in which the batter hit the ball squarely were considered successful trials; trials in which the ball was contacted with a glancing blow were considered failed trials. All trials in which there was no ball contact were discarded. The actual numbers of successful and failed contact trials were, respectively, 13 and 8 in the known situation, and 11 and 11 in the unknown situation. From each of these four groups of trials, five trials in which the batter hit the ball onto the middle and outside courses were selected for subsequent kinematic analysis. For the pitchers, the direct linear transformation method was used to calculate the three-dimensional coordinates of the body landmarks, including the center of the ball, whereas the coordinates of the body and bat landmarks for the batters were recorded with the motion capture system. The body segment parameters required for the calculation of the body CM motions were obtained from the standing height and mass of each pitcher and batter using de Leva's (1996) adjustments of the values reported by Zatsiorsky et al. (1990).

The following variables were calculated in this study: duration of various phases of pitching and batting, ball velocity at release, horizontal rotation angles and angular velocities of upper and lower trunk in the horizontal plane, bat angle and angular velocity in the horizontal plane, and joint movement indexes of the left elbow, shoulder, knee and hip based on a previous method reported by Murata (2001). The phases of the pitching action were the entire pitching phase ($T1_P$), the elevation phase of the throwing arm ($T2_P$), the elevation phase of the stride leg ($T3_P$), the stride phase ($T4_P$), and the acceleration phase ($T5_P$) (Figure 1a); for the batting action they were the entire batting phase ($T1_B$), the phase of backward bat motion ($T2_B$), the phase of weight shifting to the rear leg ($T3_B$), the stride phase ($T4_B$) and the swing phase ($T5_B$) (Figure 1b).

Two-way analysis of variance (ANOVA) (2 situations: known or unknown × 2 results: success or failure) with repeated measures was performed to test the effect of situation and batting results (success or failure) and their interaction on the aforementioned variables. Moreover, Pearson's correlation coefficient was calculated to test the relationship between phase durations of the pitcher and of the batter. Statistical significance level was set at $p<0.05$.

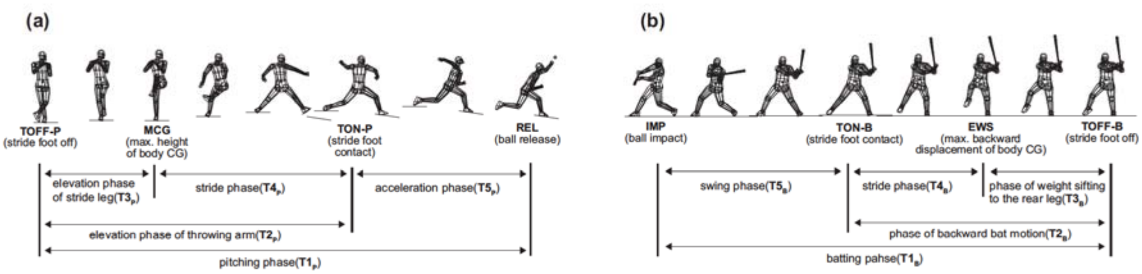

Figure 1: Definitions of each phase for (a) the pitching and (b) the batting motions.

Table 1: Correlation coefficents of each phase in the known situation between pitching and batting.

	$T1_P$	$T2_P$	$T3_P$	$T4_P$	$T5_P$
$T1_B$	0.766 **	0.730 *	0.802 **	0.214	0.327
$T2_B$	0.750 *	0.731 *	0.747 *	0.294	0.208
$T3_B$	0.686 *	0.666 *	0.710 *	0.225	0.205
$T4_B$	0.785 **	0.768 **	0.736 *	0.377	0.192
$T5_B$	0.148	0.072	0.315	-0.311	0.531

*: *p*<.05, **: *p*<.01

RESULTS AND DISCUSSION: In regard to the relationships among phase durations of pitching and batting, correlations of $T1_B$ with $T1_P$, $T2_P$ and $T3_P$, of $T2_B$ with $T1_P$, $T2_P$ and $T3_P$, of $T3_B$ with $T1_P$, $T2_P$ and $T3_P$ and of $T4_B$ with $T1_P$, $T2_P$ and $T3_P$ were significant in the known pitches situation. (See Table 1.) However, there was no significant relationship among phase durations in the unknown pitches situation. These results indicate that the batter is able to prepare in advance for the control of his timing in the known situation, because the batter is able to predict the ball trajectory. The two-way ANOVA showed a main effect of the situation on the average lower trunk angular velocity, and the value was significantly higher in the unknown situation (421 ± 71°/s) than in the known situation (346 ± 76°/s) (Table 2). Moreover, a main effect of the situation on the maximum bat angular velocity was also found, and the value was significantly greater in the unknown situation (2269 ± 145°/s) than in the known situation (2147 ± 97°/s) (Table 2). Batting is probably more difficult in the unknown situation than in the known situation, and the unknown situation possibly makes the batter spend more time deciding how to hit the ball, which in turn forces him later to use an increased speed for the bat swing. In other words, in contrast with the known situation, in the unknown situation the batter waits a relatively long time to hit the ball, until the ball is close to the batter, and then uses greater rotation speed of trunk and bat. There was a main effect of the situation on shoulder and elbow joint movement indices in the mediolateral direction, and the value in the unknown situation was larger than that in the known situation. In the unknown situation, the batter has to control his movements in response to the pitched ball, because he does not know what pitch to expect. Thus, controlling the bat not with the legs but with the arms would be important in order to address the pitched ball in the unknown situation.

Table 2: Average and maximum angular velocities (AV) of the upper and lower trunk and of the bat between the known and unknown situations.

	known	unknown	main effect
Average AV (deg/s)			
upper trunk	400±140	517±151	n.s.
lower trunk	346±76	421±71	*
Maximum AV (deg/s)			
upper trunk	817±170	939±191	n.s.
lower trunk	492±74	548±99	n.s.
bat	2147±97	2269±145	*

n.s.: not significant, *: $p<.05$, **: $p<.01$

CONCLUSION: The results in this study suggest that the timing strategy of the batting motion in the unknown situation is different from that of the known situation. The results also could provide practical implications for baseball batting practice, as an unknown-pitch situation is probably desirable, in order to improve the batter's ability to regulate the timing of batting, to rotate the trunk and bat at higher speed, and to control the bat swing with the arms.

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