BAT KINEMATICS IN BALL HITTING TASK

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The purpose of this study was to investigate relationship between timing of ball-bat impact and bat kinematics. University baseball players were asked to hit one of three kinds of ball (a baseball, a polystyrene ball, a small polystyrene ball) hung with a string. Peak velocity of the distal end of the bat appeared in different timing among ball conditions. Regardless of conditions, the lowest position of the distal end of the bat during bat swing showed up at almost same timing for each subject. These results showed that height of the distal end of the bat might be useful for estimating impact point of each baseball batter.

KEY WORDS: baseball, batting, peak velocity, impact point.

INTRODUCTION: Welch, Banks, Cook, & Draovitch (1995) researched on bat kinematics during tee batting. They illustrated that linear velocity of the bat showed the maximum at 10 ms before bat-ball impact. Messier and Owen (1984) also showed that the distal end of the bat got maximum velocity at 32ms before impact in softball batting. McIntyre and Pfautsch (1982) also exhibited that peak velocity of the bat tip was appeared in 13-16 ms before impact. These results mean that the bat collided with ball while it slowed down. In the viewpoint of physics, it seems unreasonable.

On the other hand, Gray (2002) used the minimum height of the distal end of the bat as impact point, to identify the instant of bat-ball impact in his batting simulation experiment. Unfortunately, he didn't describe why he used this kinematic parameter in detail. Though simulation experiment is useful for studying mechanism of baseball batting, it has not been established how to identify the timing of impact without hitting a ball. It is important to show validity of the way of estimating impact It is also necessary to illustrate similarities between swing under ball-hitting condition and swing without collision under simulation condition, to estimate the results of the batting from the latter condition.

The purpose of this study was to identify kinematic characteristics of the bat swing under three different ball conditions and to clarify the relationship between velocity, position of the bat tip, and impact.

METHOD: Eight baseball players in Osaka University Baseball Club participated in the study. They were asked to hit following three kinds of ball 10 times each. The order of ball condition was counterbalanced with the subjects.

Condition1. Baseball (diameter = 7.0 cm, mass = 150 g)
Condition2. Polystyrene ball (diameter = 7.0 cm, mass = 8.0 g)
Condition3. Small polystyrene foam (diameter = 1.0 cm, mass = 0.2 g)

All kinds of ball were covered with reflective tape for motion tracking. A baseball bat made of aluminum was used (length = 84 cm, diameter = 6.98 cm, mass including attached markers = 920 g).Three reflective markers were attached on the distal end of the bat. A ball was hung with a string at center position of front line of home plate and it was set at preferred height for each subject. Each subject was told to hit line drive toward the direction of center fielder. Four 240-Hz infrared cameras (Qualysis, Inc.) were used to track the markers on the bat and the ball. ProReflex Motion Capture System software (Qualysis, Inc.) was used to record and analyze the individual trials. Data were processed to calculate kinematic variables using custom programs written in Matlab (The MathWorks).

The displacement of the center of the bat tip was calculated from three markers and its velocity was calculated with differential calculus. Data were synchronized at the impact and averaged across trials in each condition. The frame of right before bat-ball impact was defined as 0 frame and time after bat-ball impact were defined as positive in time. In this study, we used global reference frame (X-axis was directed from posterior to anterior, Y-axis was directed from outside to inside of right hitter, and Z-axis indicated vertical upward).

One-way analyses of variance (ANOVA) were used to determine any differences in peak velocity of bat tip or timing by three ball conditions for individual participants ($p< .05$). Tukey's post hoc procedure was used to determine significant difference of every combination of two conditions. A one-way repeated measure ANOVA was performed to determine difference across subjects among conditions.

RESULTS: Peak velocity of the distal end of the bat is shown in Figure 1. Subject 1 showed significant higher velocity in Condition3 as well as Condition2 than Condition1. On the other hand Subject 2 and 5 did it in Condition1 than Condition3. In Figure 2, it is shown the average time at which velocity of the bat tip showed the maximum. Vertical axis indicates time lag between the frame that peak velocity appeared and the frame of the impact(1 frame = 4.2ms). All subjects except Subject 5 showed significant later peak timing in Condition3 than Condition1. In Figure 3, it is shown the average time that height of the distal end of the bat during bat swing showed the minimum. Vertical axis indicates time lag between the frame of the minimum height of the bat tip and the frame of the impact. No subject showed significant difference among three-condition (2.0 ± 3.6ms). The minimum height of the bat tip appeared within ± 2 frames of the impact, except Subject 8.

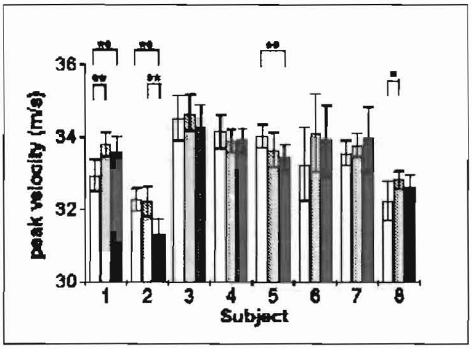

Figure 1: Peak Velocity of the Distal End of the Bat.

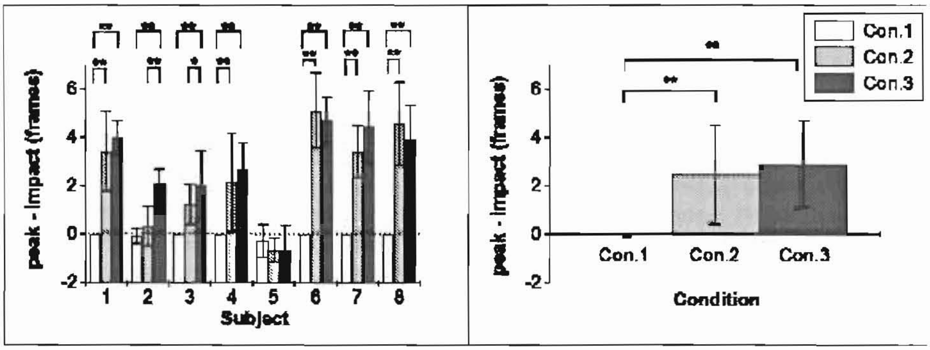

Figure 2: Temporal Relation between Peak Velocity and Impact (left: every participants, right: the mean and the standard deviation).

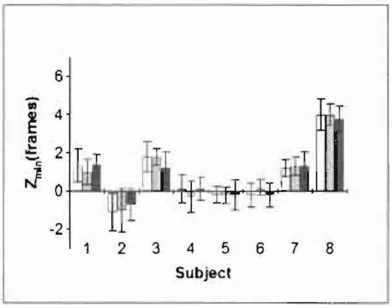

Figure 3: Temporal Relation between Minimum Z-coordinate of the Bat and Impact (left: every participants, right: the mean and the standard deviation).

DISCUSSION: Gray (2002) hypothesized that height of the bat tip showed the minimum at impact point. As shown Figure 3, it may suitable for some of subjects (Subject 4, 5 and 6). In all conditions, as it was shown that each subject carried the bat tip to minimum height with a specific time relative to the impact time, z-coordinate of the bat tip may be important factor to decide impact point. However, as Subject 8, some case may deviate from the hypothesis. It is necessary to modify it for further use in dry swing situation.

Peak velocity appeared different timing among conditions. In Condition1, at almost all swings, bat velocity showed the maximum right on the impact. However, it seemed the apparent phenomenon due to the large impulse of the collision. If the impulse is small enough, the peak velocities occurred at approximately 10ms after the impact (Figure 2). Thus, the bat-ball impact occurred while the bat increased its velocity (right panel of Figure 4). In addition, the standard deviations of the time of peak velocity were greater than those of the time of minimum height of the bat. It suggested that the peak velocity is not good for estimating the timing of the bat-ball impact, compared with the minimum height of the bat tip.

Some previous studies of interceptive actions reported that bats or rackets showed maximum velocity at least 10ms earlier than the instance of impact (Welch et al, 1995; Elliott, Marsh, & Overheu, 1989). This may result from improper filtering method. Knudson & Bahamonde (2001) presented that it is possible that velocity curve including impact may be oversmoothed with filtering. Figure 4 shows difference between raw data and low pass filtered data with Butterworth method (A fourth-order, zero phase shift. cut-off frequency = 14.9Hz). In right panel, the data of Condition1 is also drawn with dashed line for comparison. Remarkable change of velocity profile was shown in Condition1 though it was not shown in Condition3. The timing of peak velocity was 9.5 ms (= 2.3 frames) before the impact, on average in filtered data. The results agreed with those by Welch et al. (1995) very well.

The peak velocities of the bat tip in this study agreed with the results by Welch et al. (1995), but a little slower than those of McIntyre and Peautsch (1982; 39.3-42.2 m/s). Further study employing participants with wide range of playing level may be needed for generalization of the current results.

The results of Condition 2 and Condition 3 are almost same. It meant that the ball size and weight has little effect in these conditions. But, Subject 2 recorded higher swing velocity in larger ball conditions (Condition1 & 2) than in smaller ball condition (Condition3, see Figure 1). He might pay attention to spatial accuracy of the swing too much, and it might decrease swing velocity.

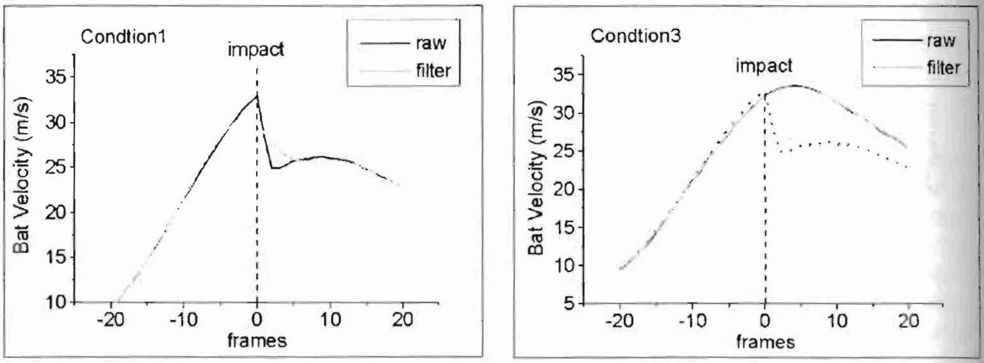

Figure 4: Butterworth Filtering Effect to Velocity Profile (Averaged Data of Subject1).

CONCLUSION: This study revealed that batters hit a ball while the linear velocity of the bat increased. It was confirmed that distal end of the bat showed minimum height in unique timing for the batter in spite of ball weight. This phenomenon may be useful for experiment under a simulationed condition. We can estimate impact point and timing as long as bat kinematics were measured, even in dry swing.

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