KINEMATIC ANALYSIS OF THE UPPER LIMB AT DIFFERENT IMPACT HEIGHTS IN BASEBALL BATTING

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The purpose of this study was to investigate the change in the upper limb motion to three different hitting areas of the strike zone: high, middle, and low. Subjects were ten right-handed male skilled batters of a university baseball team. Data were collected using a three dimensional automatic motion analysis system (Vicon 612). The joint angles of the upper limbs were computed. Comparison of the hitting in the high area vs. low area revealed that to hit the ball in the low area the batter more extended his left elbow, and flexed more his both shoulders and horizontal adduction angle of the left shoulder was large at the phase of the Left upper arm parallel (LUP). At the impact phase he flexed his left elbow more, adduction angle of the left shoulder was small in the case of the high area than the case of the low area. The opposite tendency to the high area was observed in the case of the low area.

KEY WORDS: three dimensional motion analysis, angular kinematics, striking.

INTRODUCTION: Many investigations on baseball batting have analyzed the techniques by which a batter hits a ball in the middle in the hitting areas (McIntyre, 1982; Messier 1985). However, since the pitching course in actual game varies, the batter has to modify and change the batting swing so that he or she reacts to various courses. Little information of how a batter modifies the motion to various pitching courses have been reworded. Tago et al. (Tago, 2006) reported that in case of the high, middle hitting areas, the rotation of the shoulder at the impact phase were larger than the low hitting areas. The purpose of this study was to investigate the change in the upper limb motion to the different hitting areas.

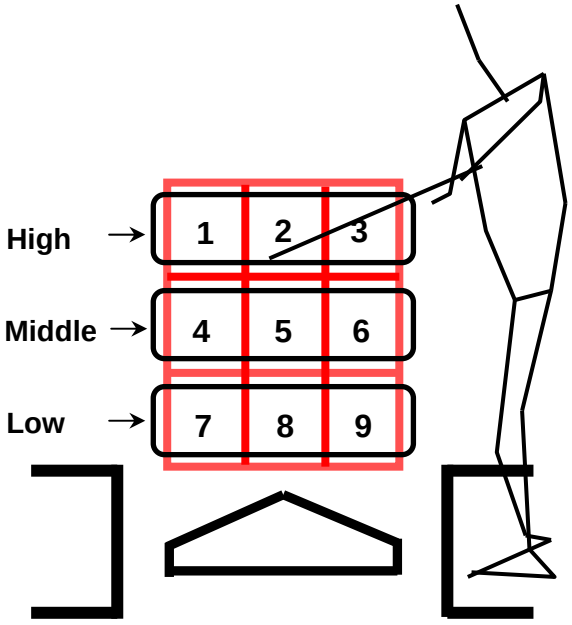
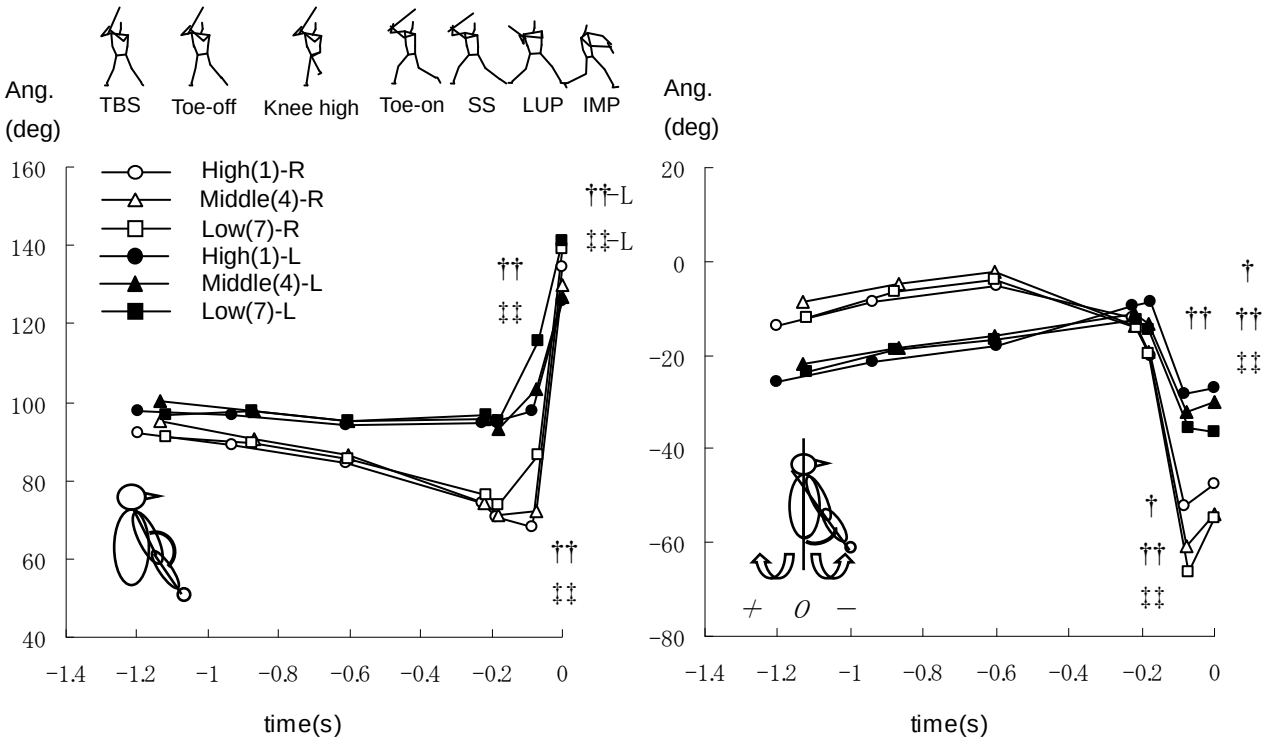


Fig.1 Hitting areas set in this study

METHODS: Subjects were ten right-handed batters of a university baseball team. Informed consent was collected after the explanation of the experiment procedure. Three different hitting areas were set in accordance to the rule of baseball. The batting tee commonly used during practice was used to modify hitting areas. The high areas for right-handed batters were defined as 1, 2, and 3 of Figure1, the middle areas as 4, 5 and 6 of Figure1, the low areas as 7, 8 and 9 of Figure1.The subjects were given the hitting areas in random order, and the position of non-stride leg was set as the same position at the beginning. The

coordinate axes were defined as follows: the Y axis was set as the direction to a pitcher, the X axis as the medio-lateral direction, and the Z axis as the perpendicular direction. Data were collected by using a three dimensional automatic motion analysis system (Vicon 612). Nine cameras operating at 250Hz were used to capture the players' motion. From several trials for each point, one trial of the fastest ball velocity and the best self-evaluation was chosen in each point and subject for analysis. For the analysis and description of data, the batting swing was divided by seven instants as follows : TBS…The phase at which the bat grip began to move toward a catcher (Start of take back). Toe-off…The phase at which the stride leg broke the contact with the ground. Knee-high…The phase at which the knee of the stride leg was in the highest position. Toe-on…The phase at which the tip of the foot of the stride leg contacted with the ground. SS…The phase at which the bat grip began to move toward a pitcher (Swing start). LUP…The phase at which the left upper arm of the batter was in parallel to the X-axis (L-upper arm parallel). IMP…The phase at which the bat contacted with the ball (Impact).
Angular kinematics computed were joint angles of the right and left elbows, and flexion-extension, adduction-abduction, horizontal adduction-abduction angle of the shoulders. Two-way ANOVA (three heights times three courses) was used to examine the difference in the angular kinematics of the phases mentioned above between hitting areas, setting significant level at 5%.

RESULTS AND DISCUSSION: Figures 2 and 3 show the average joint angles at seven phases during hitting the high and low hitting areas. Figure 2-1 shows the elbow joint angles and Figure 2-2 shows Flexion-Extension angles of the shoulder. In Figures, R indicates the right limb, L is the left limb, and one example is shown in the present study, and (1),(4),(7)

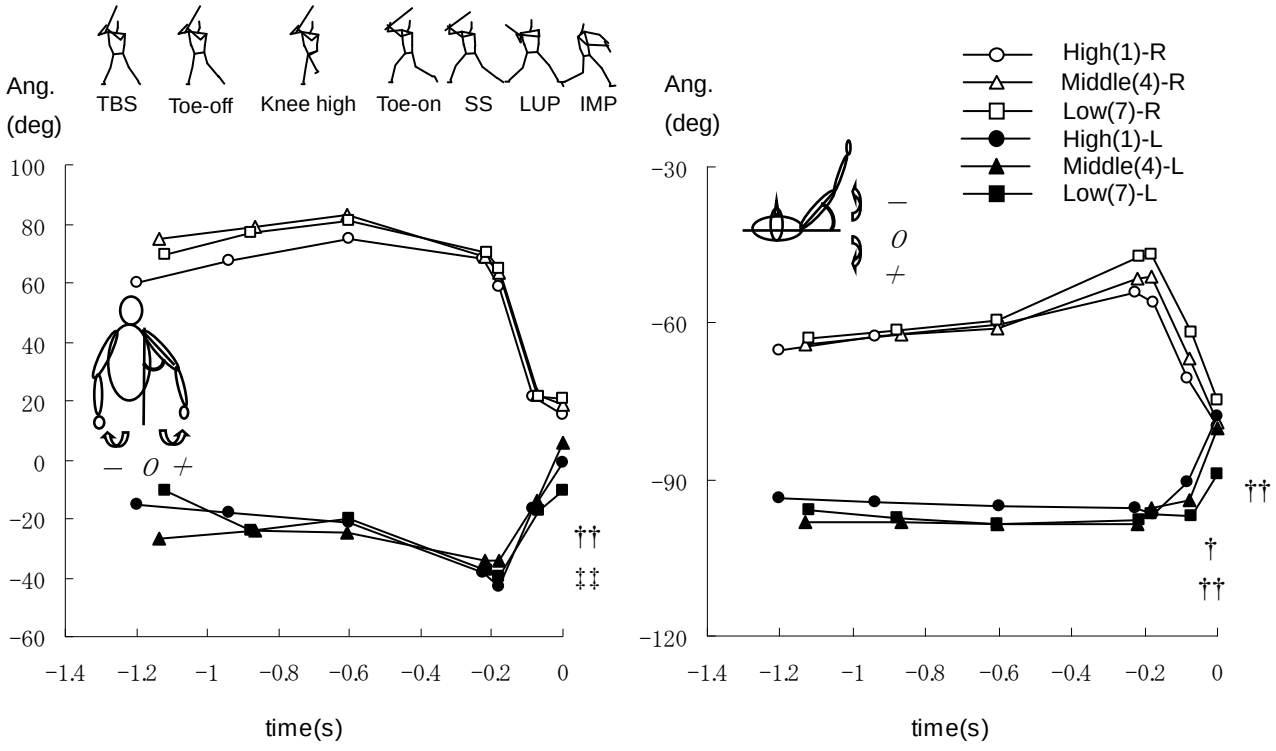


1. Elbow joint angle

2. Flexion-extension angle of the shoulder joint

Fig.2 Changes in the elbow and flexion-extension angle of the shoulder during batting in height hitting areas.
Significant difference ($p<0.05$) : High vs. Middle ; †, High vs. Low ; ††, Middle vs. Low ; ‡‡

indicates the hitting area (Refer to Figure.1). Significant differences are shown by a symbol (†, † †, ‡ ‡). And the definition of the each joint angle is shown in the picture in the graph.
In Figure 2-1, only minor change in the left elbow angle was found before the phase of the left upper arm parallel(LUP), and then the elbow joint was abruptly extended toward the impact in both hitting of high and low hitting areas. The significant difference in the elbow was observed at the phase of the LUP and impact (IMP), i.e. the elbow joint angle of the low area was larger than that of the high area. In Figure 2-2, flexion angle of the right shoulder remained constant before the swing start (SS), after that the flexion angle of the right shoulder quickly increased toward the impact in high and low hitting areas. The significant difference in the right shoulder was observed at the phase of the LUP, i.e. the flexion angle of the right shoulder at the high area was smaller than that of the low area. Extension angle of the left shoulder gradually increased toward the swing start. After that the flexion angle of this joint suddenly increased toward the impact in both high and low areas. The significant difference was observed at the LUP and IMP, i.e. the flexion angle of the left shoulder at the low area was larger than that of the high area.
In Figure 3-1, abduction angle of the right shoulder was almost constant until the phase of the SS. After that the adduction angle of the right shoulder quickly increased toward the phase of the IMP. However, no significant difference was observed at the seven phases. Adduction angle of the left shoulder was almost constant until the phase of the SS. After that the abduction angle of the left shoulder quickly increased toward the phase of the IMP. The significant difference was observed at the IMP, i.e. the adduction angle of the left shoulder at



1. Adduction-abduction angle of the shoulder joint

2. Horizontal adduction-abduction angle of the shoulder joint

Fig.3 Changes in the adduction-abduction and horizontal adduction-abduction angle of the shoulder during batting in height hitting areas.
Significant difference ($p<0.05$) : High vs. Middle ; †, High vs. Low ; ††, Middle vs. Low ; ‡‡

the low area was larger than that of the high or middle areas.
In Figure 3-2, horizontal adduction angle of the right shoulder was almost constant until the instant of the Knee-high. After that the horizontal abduction angle of the right shoulder increased toward the phase of the SS. After that the horizontal adduction angle of the right shoulder quickly increased toward the phase of the IMP. However, no significant difference was observed at the seven phases. Horizontal adduction angle of the left shoulder was almost constant until the phase of the SS. After that the horizontal abduction angle of the left shoulder quickly increased toward the phase of the IMP. The significant difference was observed at the LUP and IMP, i.e. the horizontal adduction angle of the left shoulder at the high area was larger than that of the low area.
Comparing hitting the ball in the high area with the low area, we will be able to identify that hitting a low compared with a high ball was characterized by ; the batter more extended his left elbow, and flexed more his both shoulders and horizontal adduction angle of the left shoulder was large at the phase of the LUP. At the impact he flexed his left elbow more, adduction angle of the left shoulder was small in the case of the high area than the case of the low area. The opposite tendency to the high area was observed in the case of the low area. The significant differences in selected joint angles were observed after the commencement of the swing, which may imply that adjustments occur during the forwards swing period. It was suggested that the movement of a left arm from which a significant difference was seen in all the joint angles after the commencement of the swing be especially important.

CONCLUSION: Kinematic comparisons indicated that in hitting a ball at high and low areas, the batter adjusts the position of the bat by modifying shoulder and elbow angles, particularly at LUP and modifies the angles in the left upper limb just before impact.

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