BIOMECHANICAL ANALYSIS OF BASEBALL HITTING

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Many hitting skills are involved in sports activities. Each respective skill requires a specific striking instrument to achieve its own purpose. In the case of baseball hitting, a bat must produce maximum velocity at the ball contact to get maximum momentum and distance of the ball. However, very few investigations have so far been conducted on the kinetics and kinematics of swinging a bat. Race (1961) analyzed relative angular movement of the baseball bat prior to its contact with the ball and found that the bat had a sharply increasing rate of velocity as it approached the ball. He also suggested that responsibility for this rate was made by a sequential action of body segments progressing from the striding of a foot, the hip rotation and to the hands-and-wrists action. But he did not analyze the changes in the movements of a bat and body segments. Concerning softball hitting for female, Messier and Owen (1984) examined the three-dimensional linear and angular bat kinematic parameters and calculated instantaneous values of resultant bat velocity and kinetic energy during the swing. They discussed these values in comparison with those previously obtained from baseball hitting without referring to the action of the body segments. By filming baseball hitters from above, McIntyre and Pfautsch (1982) analyzed angular movements of left arm segments when hitting a baseball to the same and opposite fields. Based on the results they concluded that angular displacements of the left wrist and left elbow joints and temporal characteristics of the swing contributed to these hitting techniques.

Considering the instruction given by baseball coaches that hitters should not rotate their hips too early when a pitched ball travels at them, it may have some meanings to calculate the kinematics of swinging a bat and to examine the mechanics of hitting from the standpoint of hip rotation.

PROCEDURE

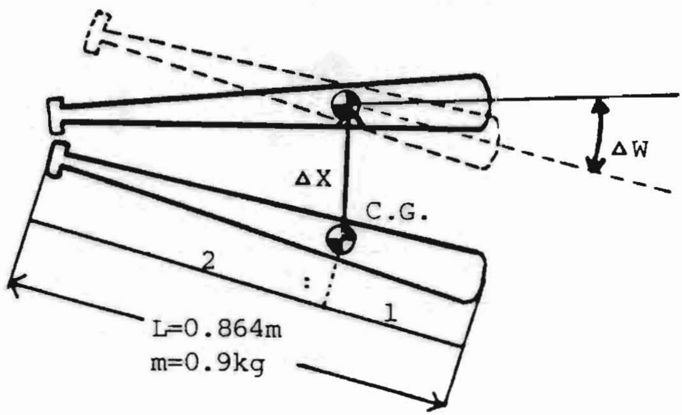
Five skilled and 2 unskilled Japanese college baseball players (all right handed) consented to participate in this study. The subjects were selected according to the evaluation made by their coach on a standpoint of their hip rotation against a pitched ball. Age (yr), body height (cm), body weight (kg), time from the landing of a striding foot to the contact of a bat with a ball (sec) and maximum linear velocity of the bat at the point of ball contact (m/sec) are listed in TABLE 1.

Each subject was asked to attach a celluloid plate (3cm wide, 6cm long) on both sides of the iliac crest to ascertain the hip rotation from above and was requested to hit a pitched baseball with a wooden bat (mass=0.9kg). Each trial was filmed from above (about 10m high) by the use of a 16mm cinecamera (200Hz), for movements of a bat and body segments were assumed to move through primarily in a horizontal plane. In order to analyze the identical hitting pattern, this procedure was applied repeatedly until each subject could hit a ball effectively to the same field.

TABLE 1
SUBJECT INFORMATION CONCERNING HITTING PERFORMANCE

subjects	Age (yr)	Height (cm)	Weight (kg)	ST* (sec)	Vi** (m/sec)
skilled					
Y.J.	21	178.0	75.0	0.20	33.7
I.H.	21	177.5	72.5	0.19	34.9
T.H.	22	177.2	70.0	0.20	28.7
M.I.	21	180.5	77.5	0.19	26.1
F.J.	20	175.6	66.5	0.20	32.3
unskilled					
M.N.	22	180.2	67.0	0.19	28.1
K.A.	20	167.3	63.0	0.20	27.2

* ;time on landing the striding foot prior to contact
**;linear bat velocity at point of ball contact



$$V = \frac{\Delta X}{\Delta t}, \quad w = \frac{\Delta W}{\Delta t},$$

Figure 1 Schema of the movement of the baseball bat

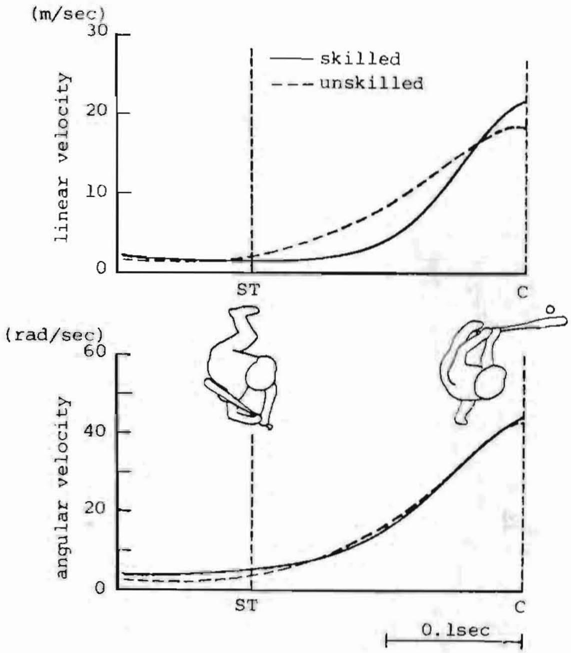


Figure 2 Changes in linear (V) and angular (w) velocities of C.G. of the bat during the swing

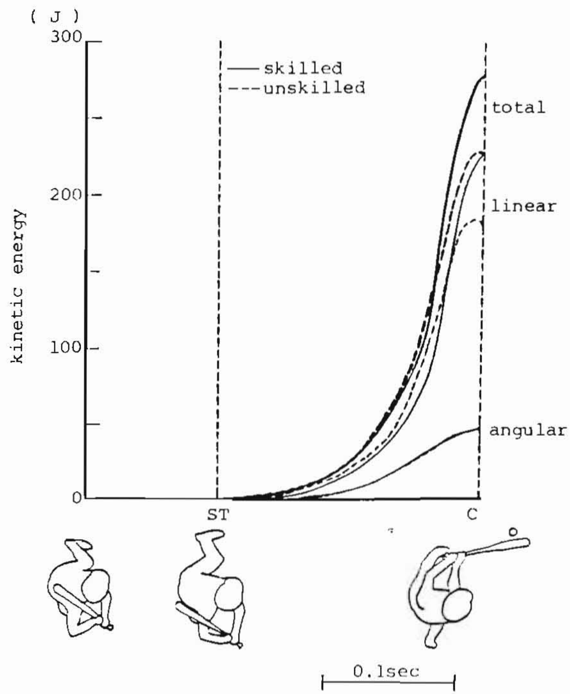


Figure 3 Changes in total, linear and angular kinetic energy of the bat during the swing

The film was digitally analyzed with a motion analyzer for 0.3sec prior to the ball contact. Two-dimensional coordinates in a horizontal plane were obtained from the tip and grip end of the bat, both iliac crests, both shoulder joints, left elbow joint and left wrist joint. Coordinates of the center of gravity of a bat (C.G.), which was defined as the one-third length from the tip of the bat, were calculated and then transformed into the linear (V) and angular (w) velocities of C.G. as seen in Figure 1. These velocities were calculated over the time for hitting the ball with the smoothing method of 5 point moving averages. Furthermore, the instantaneous kinetic energy of a bat was calculated according to the following equation;

$$K.E. = 1/2mV^2 + 1/2Iw^2$$

where K.E.=total kinetic energy of a bat, m=mass of a bat and I=moment of inertia of C.G. about the perpedicular axis. Variations in potetial energy of a bat during the swing were considered negligible with respect to the kinetic energy.

RESULTS

Changes in linear (V) and angular (w) velocities of C.G., with respect to swinging time for hitting performance, are illustrated in Figure 2. Patterns of curves between the skilled and the unskilled were observed to be similar in w, but different in V. V for the skilled was kept constant after landing of the striding foot (ST) and it was rapidly increased 0.1sec prior to the ball contact (C), whereas for the unskilled V was gradually increased after ST. For the skilled the mean maximum values of V and w obtained at C were 22.6m/sec and 42.0rad/sec, respectively. On the other hand, for the unskilled those, which occurred at an average of 0.01sec prior to C, were 19.9m/sec and 41.8rad/sec, respectively.

The time course of the total linear and angular kinetic energy of a bat during the swing are shown in Figure 3. Mean maximum values of the total kinetic energy were 274.0J for the skilled and 227.5J for the unskilled, respectively. The difference in these values was due to the difference in the maximum values of the linear kinetic energy; that is, the skilled had greater V than the unskilled immediately prior to C. But, the unskilled showed the greater values of total kinetic energy by 0.04sec prior to C.

In order to investigate the difference in the action of a bat produced by each hitting group, angles of the bat (θB) and the hip (θH) in a horizontal plane were defined as seen in Figure 4 and the relationship obtained between θBand θH during the swing was shown in Figure 5. In spite of the coincidence of the relationship for both groups at the start of hitting performance, the unskilled showed greater displacement and earlier increase in θH with respect to θB than the skilled. Concerning the change in the angular velocity of θH, which was obtained by the same method as w, it was indicated that the unskilled showed earlier and lower mean maximum value of the angular velocity in θH than the skilled (Figure 6).

Furthermore, from the measurements of angles of bat-left forearm (θF), left elbow joint (θE) and left shoulder joint (θS) in a horizontal plane during the swing, defined as shown in Figure 7, following results were obtained (Figure 8); for the unskilled,
1) the steepest phase of increase in θF appeared earlier, 2) the increment of θE appeared at about ST and its greater value was kept contant until C and 3) the decrease in θS occurred at ST and its lower value was held just prior to C.

DISCUSSION

The rapid increase in the linear velocity of C.G. of the bat during the swing for the skilled was observed at about 0.1sec prior to contact (Figure 2). Similar results were obtained from other hitting skills such as softball and golf. Messier and Owen (1984), using eight female softballers as subjects, reported that a rapid increase in bat

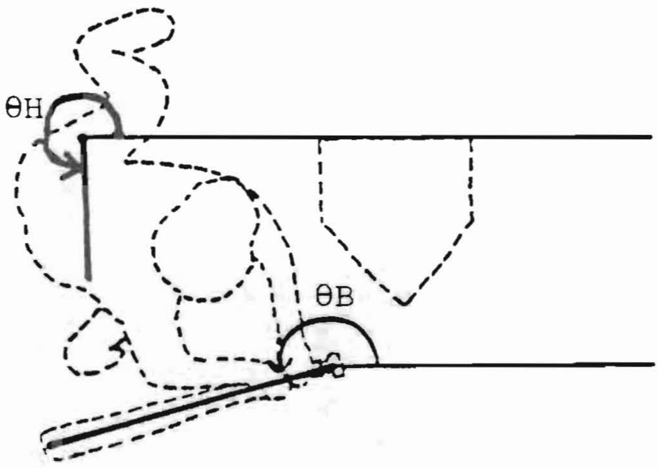


Figure 4 Angles of the bat (θB) and the hip (θH)

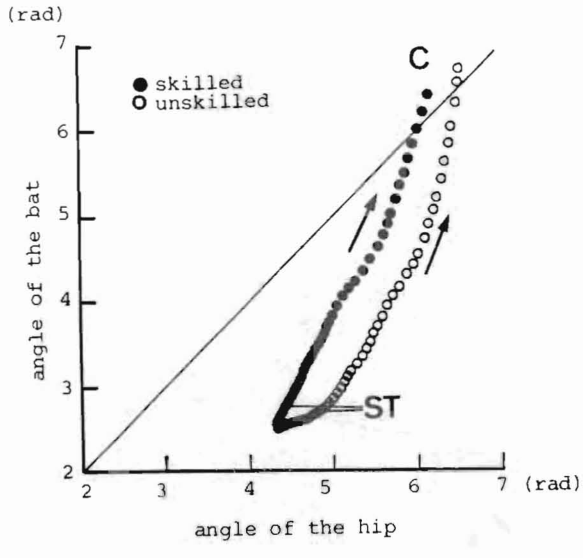


Figure 5 Relationship between angles of the hip and the bat during the swing

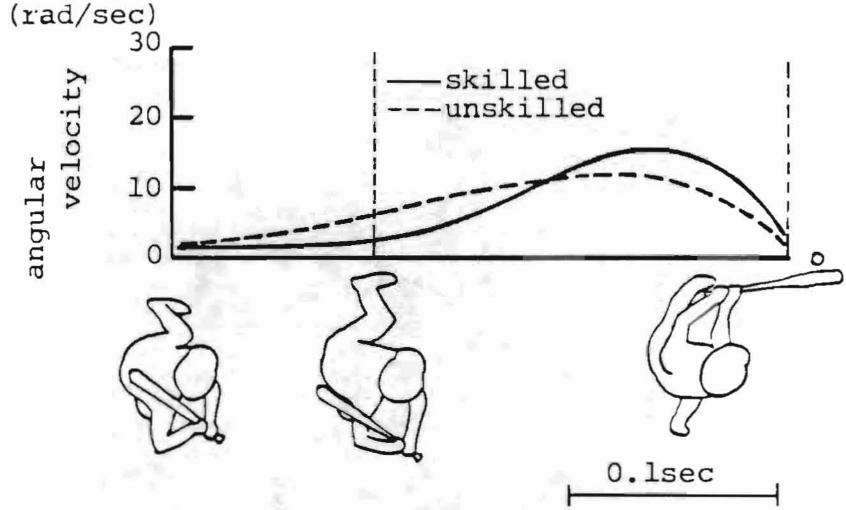


figure 6 Changes in angular velocity of the hip during the swing

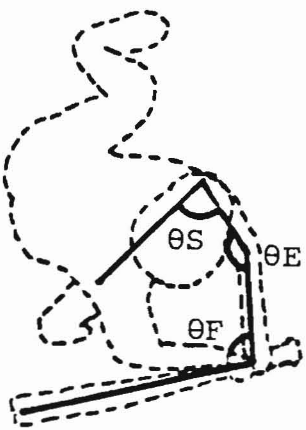


Figure 7 Angles of bat-left forearm (θF), elbow joint (θE) and shoulder joint (θS)

velocity directed toward the pitched ball began 120msec prior to contact. And by the three-dimensional analysis for the golf swing of 4 professional and 2 low-handicap amateur golfers, it was found that the sharp increase in velocity of the center of gravity of the club corresponded to the time of rapid wrist uncocking which began between 100msec and 80msec prior to impact (Neal and Wilson, 1985). Thus, it is considered to be the characteristics of the skilled that they produce rapid increase in the velocity of the striking instrument just prior to contact and get the greater velocity at contact. On the other hand, the linear velocity for the unskilled gradually increased after ST and its mean maximum value was obtained at 0.04sec prior to C. Although the decrease in the velocity of the bat is recognized in a few investigations (Messier and Owen, 1984; McIntyre and Pfautsch, 1982), several reasons are attributed to this phenomenon; e.g., misuse of the hip rotation like the unskilled in this study, fault of timing for the onset of the swing and so on. So, it is possible that even the skilled indicates the decrease in the velocity of the bat. Regarding the angular velocity of the bat, there was no distinct difference in the pattern between the skilled and the unskilled. Race (1961) found that the bat velocity, which was estimated by angular displacement of the bat, increased just prior to contact. The same result was obtained in this study.

Figure 3 shows the greater value of the mean maximum total kinetic energy for the skilled (274.0J) than for the unskilled (227.5J) at the end of the swing. Considering that changes in the mechanical energy of the bat are equal to the amount of the work done by the hitter, the unskilled seems to work inadequately for the energy flow from body segments to the bat in this phase of the swing.

Examinations of the actions of the hip and the left arm segments of the hitter were carried out with such consideration. Firstly, the action of the hip rotation was attracted the attention because it has been said that the movements in a successfully executed swing proceed in a sequential fashion with the hips, shoulder, arms, and finally the wrists and the bat being driven forcefully around to front (Hay, 1978). From the relationship between angles of the bat (θB) and the hip (θH) during the swing (Figure 5), the unskilled showed greater displacement of θH and earlier increase in θH with respect to θB than the skilled. Although it is considered that the greater the displacement in θH is, the more the amount of the work the hitter produces, the maximum angular velocity of θH for the unskilled resulted in the lower value (Figure 6). The part of the reasons for this lower value may be due to the earlier increase in θH with respect to θB. Both curves of the angular velocity of θH had one peak value, but the skilled indicated sharper pattern than the unskilled. Furthermore, the mean maximum value of the angular velocity of θH appeared within 0.1sec prior to C. This pattern for the skilled is also supported by investigation made on the handball throwing (Jöris etal, 1985), which demonstrated that the main differences between the good and the poor throwers appeared to be higher maximal segmental velocities and stronger deceleration of these segments achieved in the last 50msec.

Secondly, when taking into consideration of the action of the left arm segments of the hitter during swing (Figure 8), it is proposed by Jorgensen (1970) that from the analysis for the golf swing a delay in the uncocking of the wrists would tend to benefit the attainment of maximum segmental angular velocities. As the common aim between the golf swing and the baseball hitting is to hit a ball with a greater impact, the pattern of displacement in θF for the unskilled, which showed wrist uncocking earlier than the skilled, is not preferable. It may be considered that the horizontal flexion in θS and the extension in θE at the start of the swing in the unskilled tend to make the moment of inertia of arms larger and that it is difficult for the unskilled to increase the velocity of the distal segments such as wrist and hand. The speed of the wrist at the onset of wrist and finger flexion is said to be an important prerequisite for higher work done in the last 50msec of handball throwing (Jöris et al, 1985). It might be suggested that these actions of the left arm segments in the unskilled were

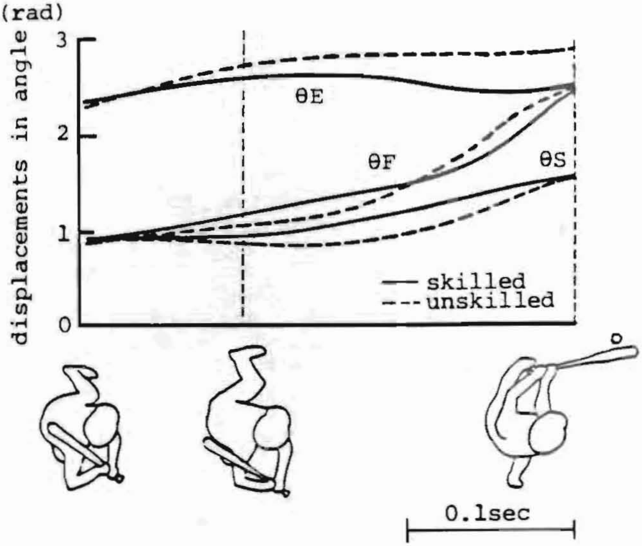


Figure 8 Displacements in θF, θE and θS during the swing

affected by the action of the hip, in which the displacement of θH increased too early with respect to θB, and that all these were responsible for the lower value of the kinetic energy of the bat.

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