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Effects of baseball bat mass and position of center of gravity on batting

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Abstract

The important characteristics to consider when analyzing a baseball bat swing include the centre of gravity, moment of inertia, and the length and mass of the bat. The present study investigated the effects of the mass and centre of gravity of a swung baseball bat. The knob of an experimental bat was equipped with accelerometers to measure the three linear and three angular components of acceleration applied to the bat when swung by trained baseball players. These six components of acceleration were measured using the experimental bat for 25 combinations of mass and centre of gravity. The mass and centre of gravity of the bat were found to affect both linear and angular acceleration during the swing. Thus, bat features relative to individual players must also be considered when analyzing the swing of a baseball bat.

Keywords: moment of inertia, mass, batting, impact, acceleration ;

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1. Introduction

A baseball player starts to swing the bat when the baseball leaves the hand of the pitcher, and the swing is completed within about 0.5 seconds [1]. Various factors affect the swing, including the physical characteristics of the bat. The bat must therefore be matched to each player after determining which physical characteristics affect the swing to allow improvements in swing technique.

Murata [2] investigated which factors affect the head speed of a baseball bat using multiple regression analysis of 11 items including physical constitution, physical strength and the weight of the bat, and assumed that the latter affected the head speed. Maeda [3] reported that the mass and position of the centre of gravity of the bat affect the head speed. However, these studies examined only swing or tee batting and did not evaluate swings performed to actually hit a pitched ball. On the other hand, Koenig et al. [4] examined the effect of the moment of inertia (a physical characteristic of the bat) on the swing speed during impact with a thrown ball. They found that when the swing speed is slow, batting performance is adversely affected for most batters and that the decrease in speed depends on the moment of inertia, which differs among batters. However, during batting, the baseball is struck in midair in front of the batter, and the effects that the physical characteristics of the bat confer upon batting are therefore difficult to determine when the analysis does not include a pitched ball.

Bahill and Karnavas [5] examined the relationship between bat weight and swing speed from the viewpoint of the kinetic energy of the bat, and found that swing speed relative to changes in bat weight differed among players. Oikawa et al. [6] and Maeda [7] reported that baseball batting swings differ among players, and thus changes in the characteristics of the bat have a different effect on the swings of different individuals.

The present study determines the effects of two physical characteristics of the bat—its mass and the position of the centre of gravity (COG)—on the acceleration applied to the bat when batting a ball pitched from the front and how these two factors affect swing type.

2. Methods

Participants

We enrolled 10 university baseball players with over 10 years of baseball experience. Table 1 shows their height, weight, hand width and baseball experience.

Experimental Bat

The present study used an experimental bat based on a normal metal bat fitted with a device that can change the mass and COG [8] by moving a weight inside of the bat (Fig. 1). Because weight was not added to the outside of the bat and the external appearance of the bat was not affected [4][9], the players were unaware of changes in the mass and position of the COG. The mass and COG did not change during the swing. The weight of the bat itself was 0.789 kg. Table 2 shows the 25 combinations of weights and weight positions used in this study.

Measurement of acceleration applied to the bat

Three accelerometers (ADXL250; Analog Devices Inc.) were attached inside the hollow knob of the handle of the bat to measure the acceleration along two directions during the swing. The accelerometers were fixed to a bolted mounting table. The grip of the bat was wrapped with tape (Fig. 1).

Figure 2 shows the linear acceleration (Lx, Ly, Lz) and angular acceleration (Rx, Ry, Rz) experienced by the bat along the X-, Y- and Z-axes, respectively.

Batting experiments

Players stood holding the bat in the batter's box as in a regular game, and batted an experimental sponge ball thrown from a distance of about 3.5 m. Acceleration experienced by the bat during the swing was measured with the accelerometer and input into a computer using an A/D converter and software (Wave-in; Library Inc.) The batting movements were simultaneously videotaped at 250 frames/s using a high-speed video camera (FASTCAM-PCI: Photron Ltd.).

The assumed sampling frequency of these measurements was 1 kHz. The players randomly batted the ball 10 times for each bat configuration.

Data analysis

For each bat configuration, the position of the COG and the moment of inertia was different (Table 2). The point at which both hands grasped the bat handle was defined as the grip position, the moment of the COG around the grip position (MCGG) was defined as the product of the mass of the bat and the distance from the grip position to the COG and the moment of inertia around the grip position (MIG) was calculated as a characteristic feature of the bat as described in Koenig et al.[4] and Fleisig et al. [9].

The composite vector Lxy was calculated as a linear combination of the measured accelerations Lx and Ly, and corresponded to the linear acceleration along the direction of the short axis of the bat. Similarly, the composite vector Rxy was calculated from Rx and Ry, and this corresponded to the angular acceleration around the short axis of the bat. Changes in the scalar quantities |Lxy| and |Rxy| were then monitored during the swing. In addition, we also calculated the effect of the linear momentum along the direction of the short axis of the bat (LMxy) and the angular momentum around the short axis of the grip of the bat (AMxy) for 0.4 seconds in each trial.

For each bat configuration and for each player, the data recorded during the 10 swings were averaged to produce profiles of the variation of Lxy and Rxy as a function of time during the swing. We also calculated the correlation coefficient between the profiles produced for different bat configurations.

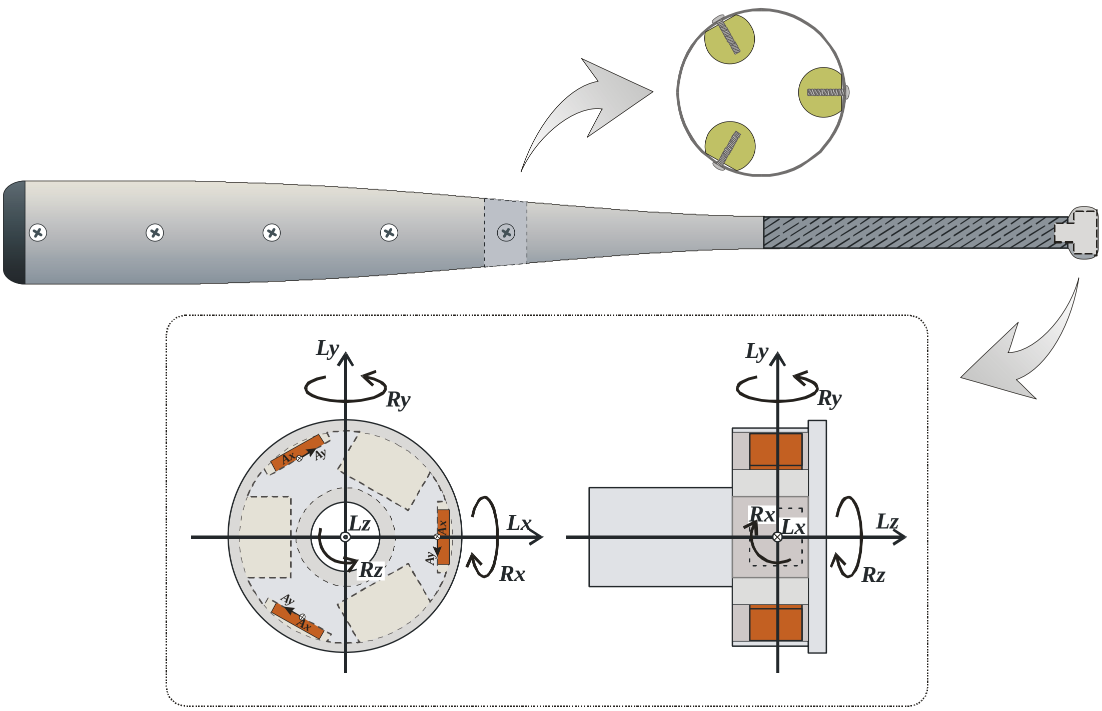

Fig.1 Experimental bat

Table 1. Characteristics of batters.

Batter	Height	Weight	Hand Width	Grip Position	Baseball Experience	Pitch	Bat
	[cm]	[kg]	[cm]	[cm]	[yrs]		
OM	179.0	62.0	8.5	10.5	12.0	Right	Left
KB	174.0	66.0	7.5	9.7	10.0	Right	Right
YH	174.0	64.0	8.5	10.8	10.0	Right	Right
TK	173.0	65.0	8.0	10.5	10.0	Right	Right
NS	171.0	78.0	9.0	10.5	11.0	Right	Right
TN	171.0	69.0	8.5	10.3	12.0	Right	Right
FK	168.5	71.0	8.8	11.3	8.0	Right	Left
NG	167.0	67.0	8.0	9.8	12.0	Right	Left
SR	165.0	62.0	9.0	11.0	12.0	Right	Left
MR	160.0	58.0	8.0	10.3	11.0	Right	Left

Table 2. Properties of the experimental bat.

Bat name	Length	Mass	Mass of Weight	Position of Weight*	Position of C.G	MOI about C.G	MOI about knob†
	[m]	[kg]	[kg]	[m]	[m]	[kgm^2]	[kgm^2]
ANN	0.838	0.886	0.097	0.498	0.501	0.0562	0.260
ASN	0.838	0.886	0.097	0.573	0.510	0.0564	0.268
AMD	0.838	0.886	0.097	0.648	0.518	0.0578	0.277
ASF	0.838	0.886	0.097	0.723	0.527	0.0596	0.287
AFF	0.838	0.886	0.097	0.834	0.536	0.0631	0.298
BNN	0.838	0.905	0.116	0.498	0.500	0.0564	0.264
BSN	0.838	0.905	0.116	0.573	0.511	0.0562	0.274
BMD	0.838	0.905	0.116	0.648	0.521	0.0578	0.284
BSF	0.838	0.905	0.116	0.723	0.530	0.0609	0.295
BFF	0.838	0.905	0.116	0.834	0.540	0.0651	0.309
CNN	0.838	0.925	0.136	0.498	0.500	0.0563	0.269
CSN	0.838	0.925	0.136	0.573	0.512	0.0561	0.279
CMD	0.838	0.925	0.136	0.648	0.523	0.0584	0.292
CSF	0.838	0.925	0.136	0.723	0.535	0.0613	0.306
CFF	0.838	0.925	0.136	0.834	0.547	0.0655	0.322
DNN	0.838	0.943	0.154	0.498	0.500	0.0563	0.273
DSN	0.838	0.943	0.154	0.573	0.513	0.0566	0.285
DMD	0.838	0.943	0.154	0.648	0.526	0.0587	0.299
DSF	0.838	0.943	0.154	0.723	0.538	0.0628	0.315
DFF	0.838	0.943	0.154	0.834	0.552	0.0675	0.334
ENN	0.838	0.962	0.173	0.498	0.500	0.0564	0.277
ESN	0.838	0.962	0.173	0.573	0.514	0.0569	0.291
EMD	0.838	0.962	0.173	0.648	0.527	0.0596	0.306
ESF	0.838	0.962	0.173	0.723	0.542	0.0631	0.324
EFF	0.838	0.962	0.173	0.834	0.555	0.0688	0.343

*, Distance from end of bat; †, located 0.0021 meters from edge of grip end.

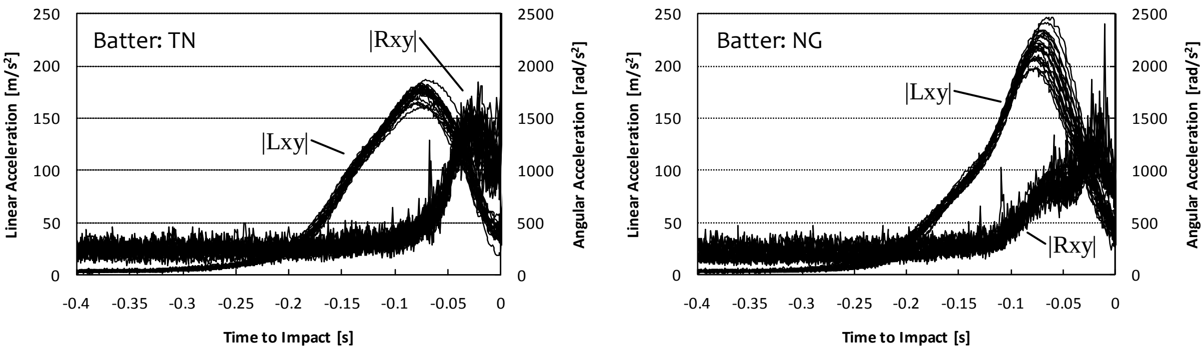

Fig. 2. Mean variation of |Lxy| and |Rxy| with time during a swing

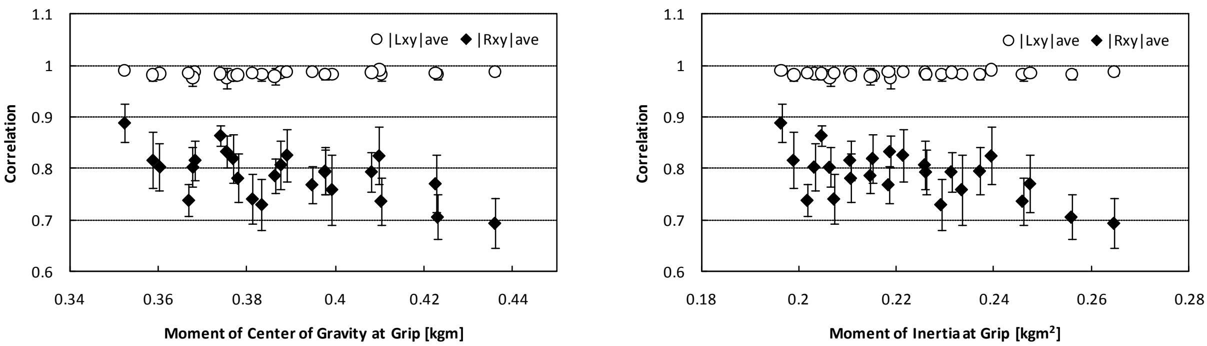

Fig. 3. Dependence of the correlation coefficients of |Lxy| and |Rxy| on MCGG and MIG for the same bat configuration for a single batter (TN).

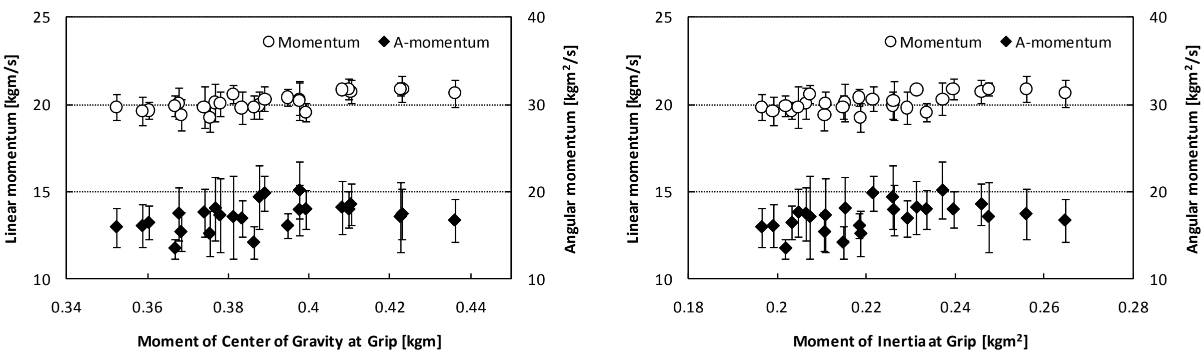

Fig. 4. Dependence of LMxy and AMxy on MCGG and MIG for the same bat configuration and the same batter (TN)

3. Results

Figure 2 shows the change in the linear and radial acceleration experienced by the bat during the swing for two different batters and for all bat configurations. As can be seen, no dramatic differences are found between individual curves for each player. On the other hand, the curves clearly differ between the two players.

Figure 3 shows the dependence of the mean correlation coefficient for |Lxy| and |Rxy| on MCGG and MIG as a function of time during a swing. The mean correlation coefficient between the different settings for most of the batters was >0.7. However, this value tended to decrease for most batters with increasing MCGG and MIG. A significant decrease in |Rxy| occurred from a MCGG of about 0.41 kgm and a MIG of about 0.24 kgm^2.

The relationship between MCGG and MIG and the linear and angular momentum of the bat at impact are shown in Fig. 4. The effects of changing the bat configuration differed among the batters. For example, AMxy changed in batter TN insofar as MCGG and MIG tended to increase at about 0.41 kgm and 0.24 kgm^2, respectively, and then became approximately constant. These changes were similar in the AMxy and LMxy of other batters.

4. Discussion

The values for |Lxy| and |Rxy| during 0.4 seconds of the swing of each batter and the pattern of acceleration applied to the bat did not remarkably change regardless of the bat configuration. Changes in the pattern of acceleration applied to the bat clearly differed among the batters, and the differences were larger than those due to the bat configuration. Furthermore, the mean of the correlation coefficient between the different settings of the bats was >0.7 for most batters, regardless of the bat configuration. In other words, each batter's swing is highly plastic, and swing movement becomes fixed and unique to each batter.

The effects of changing the bat configuration differed among the batters. For example, changes in batter TN were represented by a tendency for AMxy to increase for MCG and MIG values of about 0.41 kgm and 0.24 kgm^2, respectively, and then become approximately constant. Such changes were also recognized in the AMxy and LMxy of other batters. We considered that these changes were due to the bat swing simulating actual swings during baseball games.

The swing movement of these batters was fixed, and swing plasticity was very high. Different bat configurations did not alter the swing, but affected the momentum applied to the bat. However, even if the swing started naturally when the batter surpassed a specific range, swinging the bat to approach the point of impact was not difficult, and thus momentum equivalent to the setting of the bat was not applied. This might have been caused by the fact that the coefficients of correlation remarkably decreased from around 0.41 kgm and 0.24 kgm^2 in terms of MCGG and MIG, respectively, and thus the swing changed because swing plasticity could not be maintained.

A pitched ball is batted during baseball games, which demands the ability to consistently swing the bat and hit any kind of ball. The present method might be applicable to determining which bat characteristics are optimal for individual batters.

5. Conclusion

The swing of each batter is highly plastic and their movements become fixed and thus unique to each batter. Therefore, each batter reacted differently to changes in bat characteristics such as the mass and position of the bat COG. In other words, mass and the position of the bat COG affected the swing of each batter in a different manner and to a different degree. Thus, the mass and the position of the bat COG should be adapted to the swing of each player.

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