# TRANSFER OF ANGULAR MOMENTUM IN THE BASEBALL BATTING

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## INTRODUCTION

In a full swing batting motion, one of the most important factors should be to obtain a large amount of angular momentum from the ground, and then transfer as much of it as possible to the batting arms and also bat. Angular momentum for the combined batter-plus-bat system can be separated into two parts, associated respectively with the motions of the body-minus-batting arms ("body-minus-arms") and of the batting arms-plus-bat ("arms-plus-bat"). The purpose of this study was to clarify the changes in the angular momentum for the system during the baseball batting, and the transmission of angular momentum to the arms-plus-bat system.

## METHODS

After the take-off of the lead leg (LOF), a right-handed batter elevates the lead leg and turns the trunk toward the right, steps forward, plants the lead leg (LON), and impacts the ball (IMP) in general. The batter is in single-support (SS) phase between LOF and LON, and in double-support (DS) phase between LON and IMP. Batting motions with maximum effort by eight right-handed male varsity batters were videotaped using three-dimensional (3D) DLT procedures. The 3D coordinate data of the 21 body landmarks, the 2 bat's portions (tip and tail) and the ball center were obtained for the best battings (hit a ball squarely toward a center field) of each subject, and smoothed using quintic spline as selected by the optimal cutoff frequencies for each coordinate [3]. The coordinates were expressed in an orthogonal reference frame: The X axis pointed toward the right (normal to the direction of pitcher's mound), the Y axis the pitcher's mound, and the Z axis upward. The angular momentum values of 16 body segments and of the bat were calculated using a method based on previous study [1]. The location of the center of mass and the moment of inertia about the transversal axis of bat were measured using the balance and pendulum methods, respectively. The SS and DS phases were each divided into two equal time periods. The 3D angular momentum of the body-minus-arms, arms-plus-bat and combined system were calculated for five instants: (1) LOF, (2) the mid-point of SS, (3) LON, (4) the mid-point of DS, and (5) IMP.

## RESULTS AND DISCUSSION

Average angular momentum values for the eight swings are shown in Table 1. To facilitate the following discussion, the terms "clockwise" (CW) and "counterclockwise" (CCW) will replace the signs of the X, Y and Z angular momentum components; the directions will correspond to views from the right, from behind and from overhead for the $H_X$, $H_Y$ and $H_Z$ angular momentum components, respectively.

**Table 1**. Angular momentum ($kg \cdot m^2/s$). (M±SD)

| Times: | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| | LOF | | LON | | IMP |
| $H_X$ | | | | | |
| body-minus-arms | 1±2 | 1±2 | 1±3 | 3±4 | 3±4 |
| arms-plus-bat | 0±0 | 0±0 | 2±1 | 1±1 | 3±1 |
| system | 1±2 | 1±2 | 3±3 | 3±3 | 6±4 |
| $H_Y$ | | | | | |
| body-minus-arms | -1±3 | 0±3 | 2±4 | 1±3 | 3±3 |
| arms-plus-bat | -1±1 | -1±1 | 0±1 | 4±1 | -3±2 |
| system | -2±3 | -1±2 | 2±4 | 5±3 | 0±4 |
| $H_Z$ | | | | | |
| body-minus-arms | -2±1 | 0±2 | 4±2 | 9±2 | 3±2 |
| arms-plus-bat | 0±1 | -1±0 | 0±1 | 8±2 | 21±4 |
| system | -2±2 | 0±2 | 4±2 | 17±2 | 23±4 |

Note: Some of the values in this table may not fit perfectly with each other, because of rounding off.

The changes of the system angular momentums depend on the angular impulses of the ground reaction forces (GRFs) received by the batter's feet. The changes in the system $H_X$ and $H_Y$ values were much smaller than those of the system $H_Z$ value because little angular momentum was needed in these directions. Therefore, in this discussion, we will concentrate on the changes in the $H_Z$ value.

At LOF the system had a CW $H_Z$ of 2 $kg \cdot m^2/s$. This value changed to a CCW $H_Z$ of 4 $kg \cdot m^2/s$ at LON. Since the GRF in the XY plane pointed rightward (toward a catcher) of both feet before LOF and leftward (toward a pitcher) of pivot foot after LOF [2], the change of the $H_Z$ was produced by the horizontal GRF. The change from a CCW $H_Z$ of 4 $kg \cdot m^2/s$ at LON to a CCW $H_Z$ of 23 $kg \cdot m^2/s$ at IMP was produced by the backward and rightward GRFs of lead foot and also the forward and leftward GRFs of pivot foot during the DS [2].

At LOF, all the $H_Z$ of the system was in the body-minus-arms, and most of the changes produced in the CCW $H_Z$ during the SS by the GRF also went into the body-minus-arms. During the 1st half of DS there was a gain of $H_Z$, half of which was transmitted from the ground through the legs and trunk to the batting arms and also was generated by the legs and trunk, the remains was generated by the batting arms. During the 2nd half of DS there was a gain of $H_Z$, most of which was generated by the arms and bat.

## REFERENCES

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