Lower Body Mechanics During the Baseball Swing

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INTRODUCTION

Very little scientific effort has been spent developing training and rehabilitation protocols specific to the hitter. In order to successfully address the needs of the hitter, the biomechanics of the baseball swing must be studied and an understanding of physiological and mechanical interaction developed. This study uses three-dimensional kinematic and kinetic data to define and quantify lower body mechanics during the baseball swing.

REVIEW AND THEORY

Movement during the baseball swing is defined by both linear and rotational components (Schmidt M. et al. 1994, DeRenne C. 1993). The linear component is defined by forward movement toward the on-coming pitch. The rotational component is defined by the movement of body segments around the axis of the trunk. Researchers (Messier S.P. et al. 1985, Williams K.R. et al. 1983) have shown that the application of force by the feet to the ground promotes both linear and rotational movement during the swing motion. Other researchers (DeRenne C. 1993, Riley P.O. et al. 1991) have shown the movement of the center of mass of the body can be indicative of forward linear motion. The objective of this study is to utilize biomechanical measurement techniques and hitting theory (Lau C. et al. 1986, Williams T. et al. 1986) to define and quantify both the linear and rotational components of lower body mechanics during the baseball swing.

PROCEDURES

Subjects: Twenty nine professional baseball players were studied. The mean height was 179cm and the mean weight was 85kg. All the subjects batted right handed. At the time of testing the subjects' level of play ranged from minor league (A,AA,AAA) to major league. The mean batting average was .246 and the mean number of 'at bats' was 246.

Data Collection: Three-dimensional motion data were collected using a video based motion collection system (Motion Analysis Corporation, Inc.). The subject was filmed using six cameras at a rate of 200 frames per second. Three-dimensional ground reaction forces were collected using two force plates (Advanced Mechanical Technology, Inc.). Each force plate collected data at a rate of 1000 samples per second. The motion and force collection equipment was electronically synchronized for simultaneous data collection.

Testing: Each subject was tested at an indoor biomechanics facility. The subject was fully informed of testing procedures and asked to read and sign an informed consent prior to data collection. 24 reflective markers were applied to the subject, bat and ball. Anatomical measurements were taken including height and weight. The subject was then allowed to warm up in the data collection area. For the purpose of eliminating the possibility of mechanical variation and adjustment to a pitched or moving ball, the hitter was asked to hit baseballs placed on a standard batting tee. While the hitter warmed up, he was asked to find a comfortable tee position from which line drive hits could be directed toward the middle of the field. During data collection, the researchers, subject and coach observed each hit for solid bat/ball contact, 100% effort and line drive trajectory directed toward the middle of the field. Data from the first three hits that met the fore mentioned criteria were saved.

Calculation: The three-dimensional location of each of the 24 reflective markers was calculated with respect to a global right handed orthogonal coordinate system (global reference frame) (Figure 1). Marker position was mathematically determined based on data collected by each of the six cameras. Kinematic data was then computed using vector mathematics and local coordinate systems which were constructed using the reflective markers placed on the body. All data were filtered using a fourth-order, low pass Butterworth filter with a resultant cut off frequency of 13.3 Hz (Winter D.A. 1979).

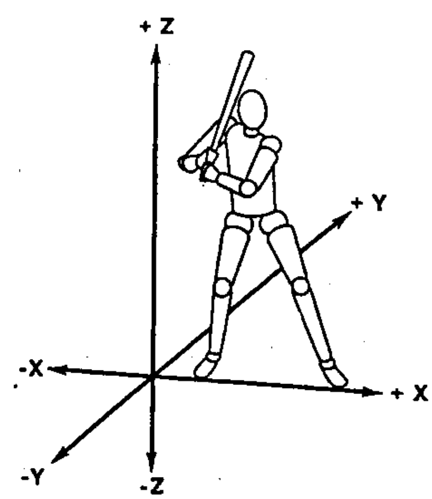

Figure 1: Global reference frame.

Parameters of measurement included stride (length and direction) and the orientation of the front foot. The whole body center of mass and the center of pressure between the feet were determined and their movement relative to each other calculated. The three-dimensional forces applied by the feet to the ground were measured, normalized to body weight and presented with respect to the global reference frame. Compressive forces were applied in the negative Z direction and shear forces were applied in the X and Y direction. The rotation of the hips (as a linked segment) around the axis of the trunk was also measured with respect to the global reference frame.

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RESULTS

(Data presented in the results are mean values)

As the hitter began the motion of the swing, he lifted his front foot causing weight to be shifted toward the back foot. The total amount of force applied by the back foot to the ground was 102%BW (percent of body weight). Shear forces of 19%BW and 2%BW were applied to the ground by the back foot in the global negative X and positive Y directions respectively. At the same time, the center of pressure between the two feet moved toward the back foot to a position 22cm behind the whole body center of mass in the global X direction.

The hitter continued the motion of the swing, by striding forward with the front foot. As the front foot came into contact with the ground, weight was shifted forward. Stride length was 84cm and stride direction was 12° closed with respect to the global positive X direction. Front foot position was 64° closed with respect to the global positive X direction. The total force applied by the back foot to the ground was 73%BW and the front foot was 8%BW. Shear forces were applied by the back foot in the global negative X and positive Y directions. Shear forces were applied by the front foot in the global positive X direction and negative Y direction. The hips were closed 23° with respect to the global positive X direction.

At ball contact, the center of pressure had moved forward in the global positive X direction toward the front foot to a position 27cm ahead of the center of mass. The total forces applied by the back foot and the front foot were 12%BW and 98%BW respectively. The hips were open 76° with respect to the global positive X direction.

DISCUSSION

General mechanics: As the hitter began the motion of the baseball swing, he 'loaded' both the linear component and the rotational component. 'Loading' the linear component consisted of transferring weight to the back foot. This caused the center of pressure to shift to the rear foot, a position behind the center of mass and thus created a dynamic situation which facilitated forward linear movement. 'Loading' the rotational component consisted of increasing the shear forces applied by the back foot in the global negative X direction and positive Y direction. This created a ground reaction force which facilitated the counter clockwise rotation of the hips.

As the hitter continued the motion of the swing, the front foot made contact with the ground ending the stride. Weight was transferred forward resulting in the forward linear movement of the center of pressure in the global positive X direction from the back foot toward the front foot. Shear force applied by the front foot increased in the global positive X direction and negative Y direction. Ground reaction to the shear forces applied by both back and front feet created a force couple at the hips. The forward linear movement of the hitter combined with the rotational movement of the hips provided a foundation for generating bat speed during the swing.

Mechanical variation: It was observed that different mechanical strategies were used by hitters resulting in a spectrum of interaction between the linear and rotational components of lower body mechanics.

At one end of the spectrum, the hitter emphasized the linear component. As the front foot made contact with the ground a forward weight transfer caused the center of pressure to gradually move to the front foot ahead of the center of mass of the body. At that point, the front foot began to apply shear forces to the ground, which facilitated the rotational acceleration of the hips. The hitter moved in a linear fashion driving his center of mass toward the position of the center of pressure at the front foot. As the hitter continued forward toward his front side, the shear force applied by the rear foot decreased. The force couple generating rotational acceleration at the hips was reduced to primarily the front foot facilitating rotation at the lead hip. The lower body action was then dominated by forward linear motion as the center of mass moved to align itself over the center of pressure at the front foot.

At the opposite end of the spectrum, the hitter emphasized the rotational component. At front foot contact, a rapid weight shift was incorporated causing the center of pressure to quickly move to a position at the front foot. In contrast to the linear hitter, the rotational hitter did not continue forward by driving his center of mass toward the position of the center of pressure, but rather, quickly shifted weight back to the rear foot causing the center of pressure to align directly below the center of mass. In this position, the force couple applied to the hips was enhanced by the combined effect of significant shear force applied by both the rear and front foot. The lower body action was then dominated by the rotational motion of the hips as the application of shear force by both the rear and front foot amplified the force couple generated.

SUMMARY

The data demonstrate a spectrum of lower body mechanics during the baseball swing. The spectrum is defined by variation in interaction between the linear and rotational components of movement. A better understanding of mechanics will allow for more specific and effective training and rehabilitation protocols.

REFERENCES

1) DeRenne C., High-Tech Hitting: Science vs. Tradition, St. Paul, MN: West Publishing Company, 1993.
2) Lau C. et al., The Art of Hitting .300, Viking Penguin, 1991.
3) Messier S.P. et al., Research Quarterly, 56(2): 138-143, 1985.
4) Riley P.O. et al., J Biomech 24(1):77-85, 1991.
5) Schmidt M. et al., The Mike Schmidt study. Hitting theory, skills, and technique, McGriff and Bell Inc., 1994.
6) Williams K.R. et al., Med Sci Sports Exerc, 15(3): 247-255, 1983.
7) Williams T. et al., The Science of Hitting, Simon and Schuster Inc., 1986.
8) Winter D.A., Biomechanics of Human Movement, John Wiley & Sons, 1979.

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