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Full Length Article

A comparison of kinetics in the lower limbs between baseball tee and pitched ball batting

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ABSTRACT

In this study, the kinetic characteristics of lower limbs during batting were investigated by comparing batting off a tee with batting a pitched ball. Participants were 10 male collegiate baseball players who performed tee batting (TB) and batting using a pitching machine (MB; approximate ball speed: 33.3 m/s). Three-dimensional coordinate data were acquired using a motion capture system, and ground reaction forces were measured using three force platforms. Lower limb joint torques were obtained by inverse dynamics calculations. The results indicated that the angular velocity of the lower trunk was larger in TB than in MB for rotation. The swing time from stride foot contact with the ground to ball impact was significantly longer in MB than in TB. The angular impulses of bilateral hip adduction, pivot hip external rotation, and stride hip and knee extension torques were significantly larger in MB, suggesting that batters exert these joint torques earlier for pitched balls to handle time constraints by changing the rotation of the lower trunk in response to the unknown ball location and speed in MB. These findings will help to fill a gap in the literature and provide coaching insights for improving batting motion.

1. Introduction

In baseball, batters try to hit the ball after it is thrown by the pitcher, adjusting their swing timing to hit the ball accurately during its short flight. Higher bat-head speed is typically needed to hit the ball harder and farther. Baseball batting is considered one of the most difficult skills to perform in all of sports (DeRenne, Morgan, Hetzler, & Taura 2008; Fleisig & Kwon, 2011; Race, 1960). Thus, previous batting studies have investigated several batting situations to clarify the techniques used by batters to adjust swing timing and generate bat-head speed.

Many previous studies have used balls thrown by a pitcher or pitching machine. Fortenbaugh, Fleisig, Onar-Thomas, and Asfour (2011) as well as Katsumata (2007) measured ground reaction forces at different pitched ball speeds and found that batters changed the maximum vertical and horizontal braking forces of the stride (lead) leg to adjust the swing timing with the weight-shift movement from the pivot (back) leg in the forward direction. An advantage of studies using pitched balls is that data on adjustment of swing

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timing can be collected under conditions similar to those in an actual game. Because this adjustment of swing timing is likely an important factor in hitting balls accurately (Matsuo & Kasai, 1994; Mastuo, Kasai, & Asami, 1993), it is difficult for batters to focus on generating higher bat-head speed when hitting a pitched ball. Thus, many baseball players practice batting through stationary ball batting using a baseball tee, focusing on the aspect of batting that they aim to improve (Dowling & Fleisig, 2016). That is, stationary ball batting can allow players to ignore temporal information (i.e., time constraints) and can thereby help them to focus exclusively on the mechanics of hitting.

Stationary ball batting (i.e., tee batting) is an effective method for collecting comparable data under the same ball conditions across all participants. However, swing timing cannot be trained using a tee. Furthermore, previous studies using a tee revealed no information on adjustment of swing timing (Ae, Koike, Fujii, Ae, & Kawamura, 2017; Iino, Fukushima, & Kojima, 2014; Inkster, Murphy, Bower, & Watsford, 2011; Messier & Owen, 1986). These studies have mainly focused on providing knowledge for obtaining higher bat-head speed in tee batting; Tabuchi, Matsuo, and Hashizume (2007) merely referred to the difference in bat movement under both conditions. However, no study has investigated the biomechanical differences between pitched and stationary ball batting, due to the difficulty of obtaining data that are comparable between the two settings. For this reason, clarifying the differences in body movement between tee and pitched ball batting will provide a step forward in the study of baseball batting.

It is likely that batters change the rotational movement of the body generated by the lower limb joints to adjust swing timing, as reported in previous studies (Ae et al., 2017; Escamilla, Fleisig, DeRenne, & Taylor, 2009b; Iino et al., 2014; Welch, Banks, Cook, & Draovitch, 1995). Some researchers have also noted that the ground reaction forces of both legs provide useful information about the lower limbs by indicating shifting of the batter's weight and swing timing (Fortenbaugh et al., 2011; Katsumata, 2007; Messier & Owen, 1985, 1986) and the sequence of muscle activity that begins in the lower limbs (Nakata, Miura, Yoshie, Kanosue, & Kudo, 2013; Shaffer, Jobe, Pink, & Perry, 1993). From these previous studies, the lower limbs are expected to play an important role in baseball batting to adjust swing timing and build mechanical energy for the motion of the swing, particularly with respect to body rotation. For this reason, it is necessary to investigate the kinetics of the lower limbs for determining joint torques associated with time constraints, to obtain results applicable to improving batting performance.

The aim of this study was to investigate kinetic characteristics of the lower limbs through a comparison of batting from a baseball tee and with a ball pitched using a pitching machine. As baseball tee and pitched balls differ in whether they require time constraints to be considered, the kinetics of the lower limbs will be affected. Against this background, we hypothesize that the difference in joint torques of the lower limbs between baseball tee and pitched ball batting contributes to handling of the time constraints.

2. Methods

2.1. Participants

Participants were 10 male collegiate baseball players (age: 20.7 ± 1.1 years; height: 1.75 ± 0.05 m; mass: 76.3 ± 7.1 kg; baseball career: 12.7 ± 2.7 years). Of the participants, six were right-handed batters and four were left-handed batters; they all had high batting skill and played regularly as members of a club in the Tokyo Metropolitan Area University Baseball League 1. All participants signed informed consent forms after receiving a detailed explanation of the study, which was approved by the Research Ethics Committee of the Faculty of Health and Sport Sciences, University of Tsukuba, Japan.

2.2. Data collection

Participants were given sufficient time to warm up using their usual routines, such as stretching, jogging, and dry swings. During the warm-up session, the preferred placement of the pivot foot (catcher's side) was established in order to remain on the force platforms and to set the same foot placement for all trials. Participants performed two kinds of batting: tee batting (TB) at belt height, which is the middle ball height of the strike zone according to baseball rules and regulations (approximately 0.83 m), and machine-pitch batting (MB) using a pitching machine (SMA30, NISSHIN SPM., Ltd., Oita, Japan). The pitching machine was located 17.44 m from the back of home plate to provide a similar point of ball release as a pitcher (Higuchi, Morohoshi, Nagami, Nakata, & Kanosue, 2013). The ball was pitched over the center of home plate at belt height, the same height as in TB, and ball speed was set at approximately 33.3 m/s (74.5 mph) for all participants, following previous studies (Escamilla, Fleisig, DeRenne, & Taylor, 2009a,b; Katsumata, 2007). Approximately 2 s before each ball was pitched in the MB cases, an assistant signaled to the participant that the ball was imminent. An aluminum bat (length: 0.84 m; mass: 0.89 kg) and hard baseballs (mass: approximately 0.15 kg) were used. Participants were instructed to hit the ball in a line drive in the direction of the pitcher. The trial selected for analysis from each participant was the one with the highest performance among successful trials, as judged by three components: hitting the ball in a line drive, the participant's self-rated score (5, an excellent trial; < 3, an unsuccessful trial), and the evaluation by a baseball coach at our university baseball club. A successful trial was achieved for TB after a mean of 4 ± 1.2 attempts and for MB after a mean of 5 ± 1.3 attempts. Because all participants were experienced baseball batters at the collegiate level, we judged that a single trial for analysis would provide enough information to describe the batting performance of each participant, as has been reported in a previous study (Ae et al., 2017).

Three-dimensional coordinate data of the batting motion (body: 47 markers; bat: 6 markers) were captured using a 16-camera motion capture system (VICON-MX, Vicon Motion Systems, Ltd., Oxford, UK) operating at 250 Hz. The positions for reflective marker placement on the body and bat were determined using a previously reported method (Ae et al., 2017; Suzuki, Ae, Takenaka, & Fujii, 2014). Cameras were fixed on tripods and placed around the analysis space (3 × 3 × 2.5 m). Ground reaction forces of the individual