BIOMECHANICAL ANALYSIS A SEQENCE OF ANGULAR VELOCITY AND COORDINATED MUSCLES ACTIVITY DURING BASEBALL HITTING

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The purpose of this study was to analyse a sequence of rotations and coordinated muscles activities of upper body. Using kinematic and EMG data from 3 recreational university baseball players participating in this study, we computed the angular velocity of trunk, pelvis, bat and trunk-pelvis rotation angle and PMT of upper body muscles. Trunk-pelvis rotation angle was 22 ° before the bat-ball contact. The pelvis, trunk, and bat showed a sequence of angular velocity beginning with the hip, followed by the trunk, and end tip of the bat. Additionally, PMT of upper body muscles generated right pectoralis major(1.03 sec.), right external oblique(1.11 sec.), left thoracloumbar fasci(1.12 sec.), left external oblique(1.13 sec.), right latissimus dorsi(1.15 sec.), left latissimus dorsi(1.16 sec.), right thoracloumbar fascia(1.16 sec.), left pectoralis major(1.25 sec.), on at a time during baseball hitting motion. PMT of upper body muscles were related to the shifting and rotating of body segment and this action can be considered the coordinated muscle activities of upper body.

KEY WORDS: sequence of angular velocity, coordinated muscles activity, baseball hitting.

INTRODUCTION: The baseball hitting is one of the most difficult techniques in sport to learn (DeRenne, 2007). In order to achieve hitting skill, rotation angle and angular velocities of the body segments are important kinematic factors (Welch et al., 1995; Escamilla et al., 2009). The bat velocity is generated from sequential rotational movements of the body with coordinated muscle activity during the bat swing (Race, 1961; Szymanski & DeRenne, 2010; Reyes et al., 2011). The coordinated muscle activations of upper body are important for stabilization of body and transmission of power. Therefore, the purpose of this study was to quantify a sequence of angular velocity of pelvis, trunk, bat and coordinated muscle activities of upper body during baseball hitting.

METHODS: Three subjects (age = 25.8 ± 2.6 years, height = 176 ± 2.5 cm, mass = 72.4 ± 5.3 kg) participated in this study. Subjects were right-handed hitters who playing local baseball league and completed 5 times of the baseball hitting task using the T-ball (Figure 1).

Figure 1: Baseball hitting motion.

Kinematic data were collected simultaneously with the EMG data using a six CCD camera video system (Motion Master 100, Visol, Korea) sampling at 100Hz. Reflective markers (1.5 cm in diameter) were placed over the right, left toe on the shoes, calcaneus, lateral malleolus, medial malleolus, lateral tibia, lateral epicondyle, medial epicondyle, lateral thigh, greater trochanter, anterior superior iliac spine, 3th metacarpal head, lateral aspect of head of ulnar, lateral aspect of head of radius, humeral lateral epicondyle, humeral medial epicondyle, lateral acromion, head and forehead, 7th cervical vertebrae, 12th thoracic vertebrae, middle of posterior superior iliac spine, bat grip, end of bat. We analyzed kinematics of the baseball hitting, sequence in peak angular velocity of pelvis, trunk, bat and rotation angle between pelvis and trunk.
Electromyography was recorded with surface electrodes placed over the motor point of the right and the left pectoralis major, latissimus dorsi, erector spinae, abdominal oblique muscles (Delsys Trigno wireless EMG system, gain = 1,000, input impedance > 10 Ω, CMRR > 100 dB, Delsys Inc., USA). EMG signal was sampled at 1 kHz by a data acquisition system (PCI-6221; National Instruments, Austin, TX, USA) and band pass-filtered (10–500 Hz). Sampled EMG data were rectified and low pass-filtered (Butterworth zero-phase 4^{th} order filter) to derive the envelope of EMG. In Figure 2, EMG was processed by a custom-made program in Matlab ver. 6.5 for determination of muscle contraction timings, such as premotor time (PMT). To determine the onsets of EMG, the threshold of each signal was determined as the mean value added to 3-times the standard deviation (mean + 3SD) at the baseline (during 1 s just before the visual stimulation). Onset was determined by using a sliding window of 100 msec, namely, the initial time of the window was recorded as onset if the mean of the samples in the window exceeded the threshold.

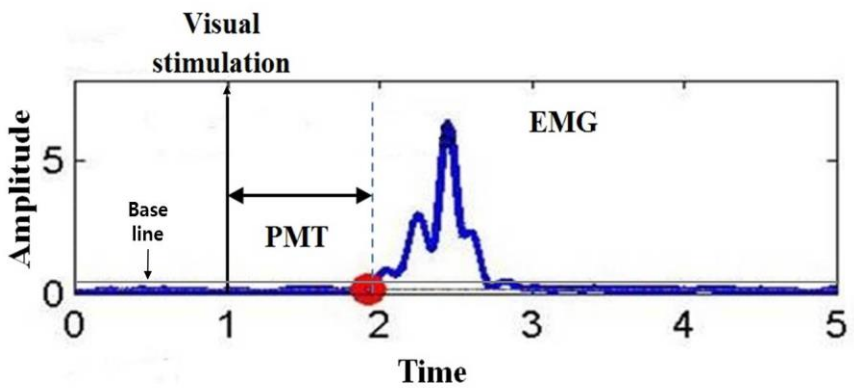

Figure 2: Premotor time (PMT) of upper body muscles during the baseball hitting. Vertical axis is a amplitude of emg(*u*V) and horizontal axis is time(seconds). Black bold Vertical line represents the time of visual stimulation and red circle spot is represented the upper body muscles onset time after visual stimulation.

RESULTS: Upper body angular velocity and rotation angle are shown in Table 1. As a result, the maximum trunk-pelvis rotation angle was 22.43°. at the approached Impact position. The sequence of peak angular velocity was occurred as this order during the baseball hitting (Figure 2): pelvis (388.83 °/s) < trunk (600.61 °/s) < bat (1952.78 °/s). The upper body muscles onset time which is a PMT was also occurred as this order: right pectoralis major (1.03 s) < right external oblique (1.11 s) < left thoracloumbar fasci (1.12 s) < left external oblique (1.13 s) < right latissimus dorsi (1.15 s) < right thoracloumbar fascia (1.16 s) = left latissimus dorsi (1.16 s) < left pectoralis major (1.25 s).

Table 1
Sequence of kinematic factor and EMG PMT

Variable	Value
Trunk-Pelvis rotation angle	-22.43 (°)
Peak Trunk Angular Velocity	600.61 (°/s)
Peak Pelvis Angular Velocity	388.83 (°/s)
Peak Bat Angular Velocity	1952.78 (°/s)
Pectoralis Major_R	1.03 ± 0.62 s
Pectoralis Major_L	1.25 ± 0.55 s
External Oblique_R	1.11 ± 0.61 s
External Oblique_L	1.13 ± 0.62 s
Latissimus Dorsi_R	1.15 ± 0.56 s
Latissimus Dorsi_L	1.16 ± 0.66 s
Thoracloumbar Fascia_R	1.16 ± 0.65 s
Thoracloumbar Fasci_L	1.12 ± 0.37 s

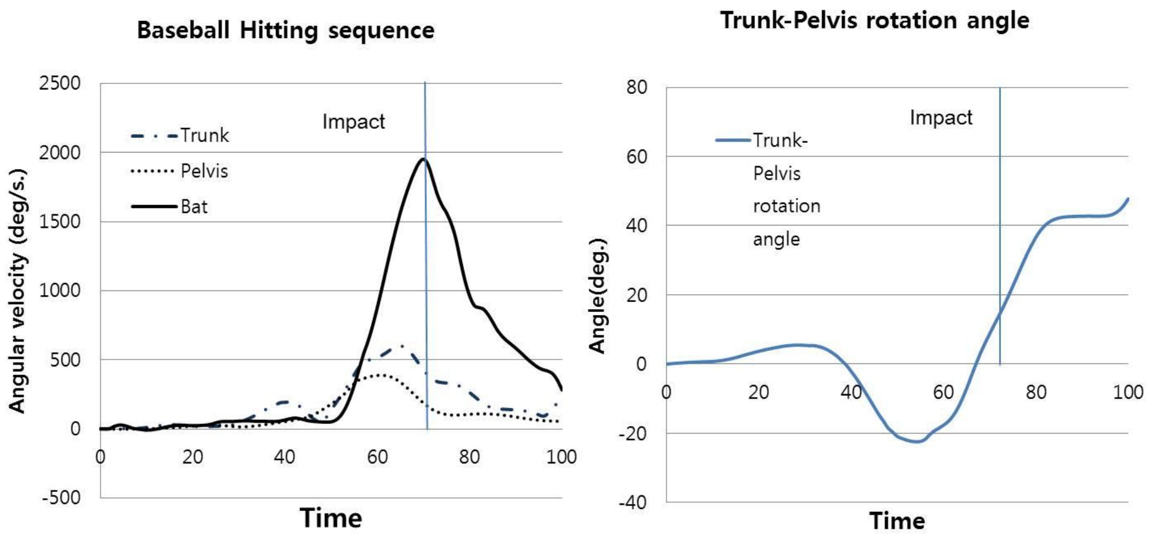

Figure 3: Baseball hitting sequence and trunk-pelvis rotation angle

DISCUSSION: The quantitative analysis of body movement and muscles activation can well described how hitting it is for baseball swing. In this study, we used T-ball to observe angular motion of the body segment and PMT of upper body muscles during the baseball hitting. Peak trunk-pelvis rotation angle showed 22 ° before the bat-ball contact in this study. As the left forefoot move forward, the pelvis segment is rotated in count-clockwise direction more than the trunk did. After the bat-ball contact, although trunk continues to rotate on a vertical axis, pelvis rotation angle is relatively small.

Welch et al. (1995) reported that peak trunk-pelvis rotation angle showed 33 ° from foot off to ball contacting from hitting motion. Escamilla et al. (2009) reported that peak trunk-pelvis rotation angle was 22°. Race (1961) summarized that the rotary motion of the baseball swing was initiated by dramatic hip rotation. During the baseball hitting, the pelvis, trunk, and bat showed a sequence of angular velocity beginning with the hip, followed by the trunk, and end tip of the bat(Figure 3).

This sequencing is related to the momentum and is transferred from larger, slower moving segments earlier in the swing to smaller, faster moving segments later in the swing (Escamilla et al., 2009; Welch et al., 1995). It creates the coordinated muscle activations of upper body during the hitting motion. Reyes et al. (2011) and Szymanski & DeRenne(2010) suggested that skilled hitters reached their highest muscle activity earlier in the swing motion.

CONCLUSION: The purpose of this study was to analyse a sequence of rotations and coordinated muscles activities of upper body. For all baseball hitting motions, the quantitative values of angular velocity showed a systematic sequence from pelvis, trunk to bat. Also, PMT of upper body muscles were related to the shifting and rotating of body segment and this action can be considered the coordinated muscle activities of upper body.

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