BIOMECHANICAL ANALYSIS OF MOTION OF PROFESSIONAL BASEBALL PITCHERS

[1]Kei Aoki

[1]National Institute of Advanced Industrial Science and Technology (AIST), Tokyo, Japan
email: aoki-kei@aist.go.jp, web: http://www.dh.aist.go.jp/

INTRODUCTION

Baseball is one of the most popular sports in Japan. According to the census of 2005, the players per year are more than 9.7 million persons, including about 3 million student players. However, a large number of student pitchers suffer injury to their throwing arms. On the other hand, these pitchers desire to improve their pitching ability, even if they are injured. Therefore, it is important to clarify the mechanism of the pitching motion of the baseball player who keeps playing baseball for a long time at the forefront of the professional baseball league and has little injury.

Our purpose is to examine the characteristics of pitching motion of a veteran professional Japanese pitcher by comparison with a recruit pitcher. The measured pitching motions were evaluated using energy consumption calculated from joint power. This energetics of the pitching motion was expressed as two quantitative indices, called "distribution ratio of joint concentric energy" and "pitching efficiency."

METHODS

Two Japanese subjects were examined. One was a 46-year-old veteran pitcher (Subject A, 1.76m, 84.6 kg, left-hander). He had his 28-year professional career and was still an active player. Another pitcher for comparison was a 24-year-old recruit player and had his 2-year professional career (Subject B, 1.82 m, 84.1 kg, right-hander).

Fig. 1 shows our measurement condition. Fifty seven markers were attached on each subject. Pitching motions were measured using motion capture system (VICON Nexus, VICON) including 16 cameras and floor force plates (BP400-600-1000PT, AMTI). Measurement frequency was 250 Hz. Pitcher's mound was flat and a catcher was prepared for catching a pitched ball 18.44 meters ahead from the pitcher's mound. The catcher crouched and took catching posture. Subjects pitched a fastball to the catcher just like their usual practices. The velocity of the ball was measured using high-speed camera (MEMRECAM GX-1, NAC Image Technology). The proposal for this study was approved by the Institutional Review Board on ergonomic research, AIST.

Measured motion data were analyzed using a 3-D biomechanical rigid segment model (Visual3D, C-Motion). The whole body of the model was divided into head and neck, upper torso, lower torso, right and left upper arms, right and left forearms, right and left hands, right and left thighs, right and left shanks, and right and left feet. Analyzed results were calculated as time-series data of joint angle, joint moment, and joint power. This joint power was integrated into energy consumption. The time-series data were divided into windup phase (WU), early cocking phase (EC), late cocking phase (LC), acceleration phase (AC), and follow-through phase (FT) as shown in Fig. 2. Refer the details to [1].

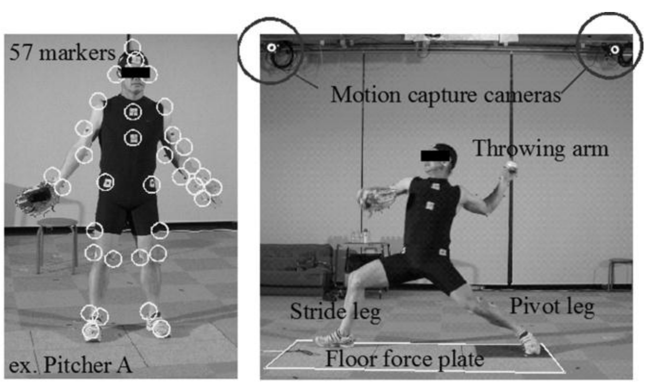

Figure 1: Measurement condition (ex. Subject A).

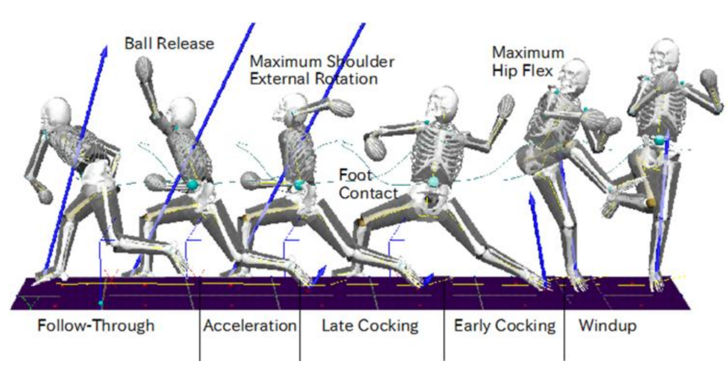

Figure 2: Definition of pitching phase.

In order to analyze the pitching motion using biomechanical energetics, concentric joint energy consumption during EC phase, LC phase and AC phase were calculated, respectively. The concentric joint energy consumption was added up at pivot leg, torso, and throwing arm. Each consumption rate of the sum of the concentric joint energy consumption in the whole body was defined as "distribution ratio of joint concentric energy" (DRE). This ratio means degrees of contribution of each part and/or each phase to acceleration of a ball in the direction of home plate. Furthermore, "pitching efficiency" (PE) was defined as the kinetic energy of a ball per the joint energy consumption of the whole body from EC phase to AC phase. If the ball velocity is larger or the joint energy consumption is lower, the PE is larger. This value means the endurance of pitching.

RESULTS AND DISCUSSION

Fig. 3 shows the representative DRE of subject A and B. The DREs of the pivot leg during EC and LC phase of subject A were higher than those of subject B. Plus, the DRE of the torso during AC phase of subject A was also higher than that of subject B. Reversely, the DRE of the throwing arm during AC phase of subject A was lower than that of subject B. These results indicate that subject A pitches using his pivot leg an torso better and makes the load of his throwing arm smaller than subject B. This result suggests that a pitcher who can use leg and torso well can keep playing baseball for a long time without great injury.

Table 1 shows the representative PE of both subjects. The PE of the subject A was larger than subject B in spite of his slower ball velocity. This result shows that subject A pitches more efficient than subject B. Fig. 4 shows the breakdown of the energy consumption of the whole body. In Fig. 4, the whole body eccentric joint energy consumption during EC phase of subject A is especially smaller than that of subject B. Reversely, the pivot leg concentric joint energy consumption during EC phase of subject A is larger than that of subject B. These results show that subject A can use his pivot leg more actively to push his body forward on the pitcher's mound. This action seems to contribute the reduction of the pivot leg concentric joint energy consumption during the next LC phase. On the other hand, subject B use eccentric energy to support his pitching posture. This usage of subject B seems to cause larger energy consumptions than subject A.

CONCLUSIONS

We analyzed pitching motion of a veteran professional Japanese pitcher (subject A) from a viewpoint of biomechanical energetics. As a result, subject A pitches efficiently using his whole body, especially his pivot leg during EC phase well. This motion strategy also seems effective for the prevention of injury to throwing arm. Our future work will be to verify the effect of the strategy and to increase subjects and trials.

REFERENCES

1.Lin HT, et al. *J Chinese Institute of Engineers* **26**, 861-868, 2003.

Table 1: Pitching efficiency.

	Subject A	Subject B
Ball velocity [m/s]	33.6	36.9
Ball kinetic energy [J]	79.0	95.3
Whole body energy [J]	918.0	1237.1
Pitching efficiency	0.0861	0.0770

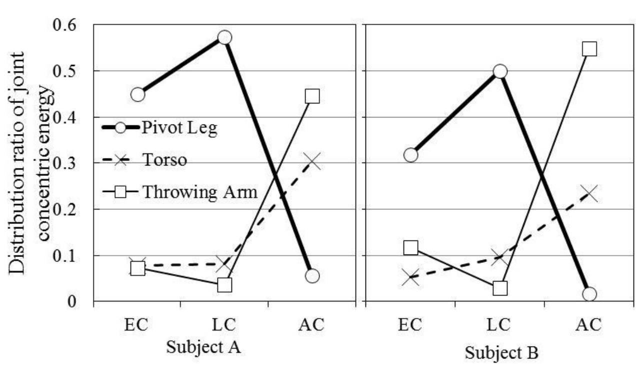

Figure 3: Distribution ratio of joint concentric energy

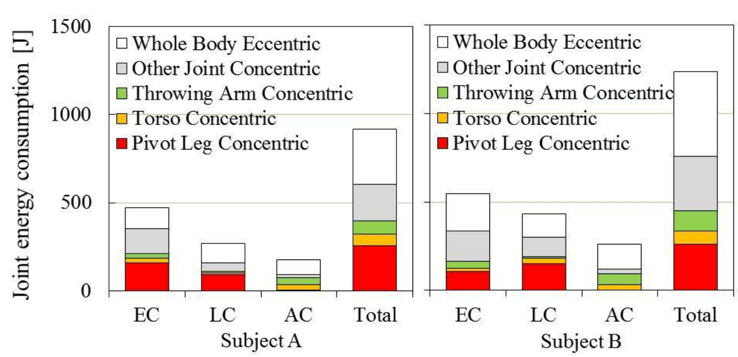

Figure 4: Breakdown of the whole body energy consumption.