BIOMECHANICAL ENERGETIC ANALYSIS OF PITCHING MOTION OF PROFESSIONAL JAPANESE BASEBALL PITCHERS

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INTRODUCTION

Baseball is one of the most popular sports in Japan. According to the census of 2005, the players are more than 9.7 million persons, including about 3 million student players. If these young players keep playing baseball for a long time in their lives, the profitable and long tail effects are expected as follows; (1) healthcare of the players themselves, (2) stimulation of the community to which the players belong, (3) economic boost for the increasing supply of the baseball equipments. These effects also contribute the prosperity of the professional baseball league. For this issue, the players need not only to prevent injury but also to progress or maintain their ability. Especially, a lot of pitchers tend to have a frequent occurrence of injury to throwing arm. 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. The pitching motion was evaluated quantitatively using energy consumption calculated from joint power, and 2 quantitative indices were defined, 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 rookie 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 motion was measured using motion capture system (VICON Nexus, VICON) including 16 cameras and floor force plates (BP400-600-1000PT, AMTI). Measurement frequency was 250 Hz. A pitcher's mound was flat and a catcher took a catching posture 18.44 m from the pitcher's mound. 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.

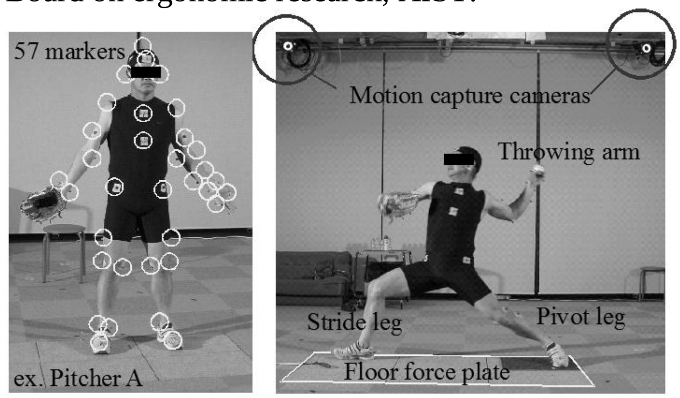

Figure 1: Measurement condition (ex. Subject A).

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].

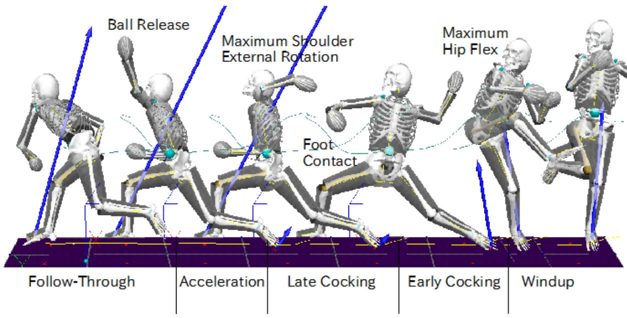

Figure 2: Definition of pitching phase.

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 whole body better and makes the load of his throwing arm smaller than subject B.

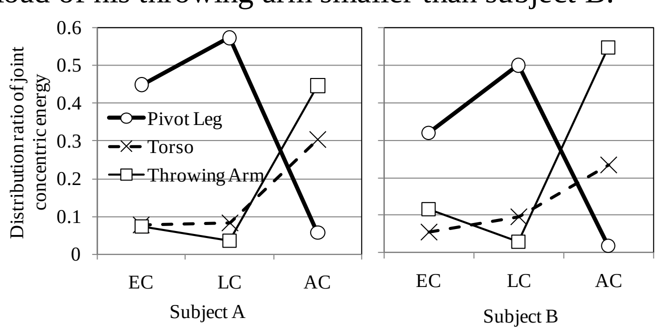

Figure 3: Distribution ratio of joint concentric energy

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 mean that the body of subject A is pushed out actively with his pivot leg 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.

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

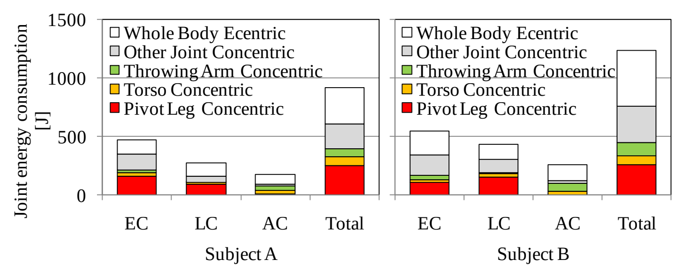

Figure 4: Breakdown of the whole body energy consumption.

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, increasing subjects and trials.

REFERENCES

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