Mechanical energy flows between body segments during baseball pitching

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Purpose

Although many investigations and books on baseball pitching estimate the occurrence of mechanical energy transfer or transfer of momentum in the body segment from the leg to the ball (House, 1989; Matsuo et al., 2001), only a few investigations of the energy flow during pitching have been done. The purpose of this study was to observe the energy flows from the legs to the ball through the torso and the throwing arm during baseball pitching.

Methods

Pitching motions of 23 varsity baseball players were videotaped with two high-speed video cameras (200fps), and ground reaction force data of both legs were obtained with two force platforms (250Hz). Three-dimensional coordinates of the body landmarks and the center of the ball were obtained by a DLT technique. Ground reaction force data were synchronized with the coordinate data. Joint torque powers, joint force powers, and segment torque powers were computed in the lower and upper limbs and torso by an inverse dynamics. The joint torque powers were integrated by the time of the pitching phases to find the amount of out energy generation and absorption by the joint torque, and the joint force powers and segment torque powers were integrated and used to see energy flows between the segments.

Results and discussion

Fig. 1 shows summary of the mechanical energy flow during pitching. During body lowering phase (Fig. 1a), power indicated the energy transferred to the distal segment at the hip and knee joints of the both legs.

![Fig. 1 Mechanical energy flows between segments during body lowering (a), upper torso energy increasing (b), ball velocity decreasing (c), late cocking (d), and acceleration (e) phase (unit in J).](image-url)
The torques of hip, knee, and ankle joints of the pivot leg absorbed small energy. Large energy inflows toward the lower and upper torsos occurred to increase the energy level of the upper torso (Fig. 1b), which was generated by the hip extension torque of the pivot leg. There was a significant relationship between the energy generated by the hip joint torque and increase in energy of the upper torso ($r=0.491$, $p<0.05$). The joint force and torque of the torso contributed to transfer energy from the lower torso to the upper torso ($96\pm30$ J and $119\pm30$ J). After the energy level of the upper torso reached the peak, the forward twisting torque of the torso generated power, and the angular velocity of the upper torso about the longitudinal axis increased, as shown in Fig. 2.

Fig. 3 shows joint forces of the throwing arm during the late cocking phase (min. ball velocity to max. external rotation of the throwing shoulder) and the acceleration phase (max. external rotation of the throwing shoulder to ball release). Large energy flows to the distal segment by the joint forces were observed at the throwing shoulder ($97\pm26$ J), elbow ($198\pm41$ J), and wrist ($109\pm25$ J) joints during the late cocking phase (Fig. 1d). In this phase, the joint force of the shoulder was large and caused the external rotation of the shoulder. At the elbow and wrist joints, generation and absorption of the energy were small, and the internal rotation torque of the throwing shoulder absorbed the energy during this phase. Energy of the forearm and hand increased ($45\pm15$ J and $72\pm17$ J) while the energy of the upper arm slightly decreased ($-3\pm23$ J). During late cocking phase, the ball velocity was almost same as the hand velocity and the energy of the ball did not largely increased yet.

During the acceleration phase, after the explosive internal rotation of the shoulder, the ball velocity rapidly increased and exceeded the hand velocity ($32\pm2$ m/s and $16\pm7$ m/s at REL). The energy of the hand was transferred to the ball ($51\pm8$ J) while the energy changes in the hand, forearm and upper arm were small.
(15±9 J, -18±12J, -20±13 J, respectively). These results indicated that the mechanical energy in baseball pitching which was generated by the hip joint torque of the pivot leg was transferred to the hand by the joint forces of the throwing arm and further to the ball by the internal rotation of the shoulder during the acceleration phase.

![Diagram of joint forces](image)

**Fig. 3** The joint forces of the throwing shoulder and elbow during late cocking and acceleration phases.

**References**
