XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

BIOMECHANICAL CHANGE OF THROWING MOTION DUE TO CHANGE IN BALL MASS

Norihisa FUJII
Faculty of Health and Sport Sciences, University of Tsukuba, Japan
E-mail: nfujii@taiiku.tsukuba.ac.jp
Web: http://lasbim.taiiku.tsukuba.ac.jp/

INTRODUCTION

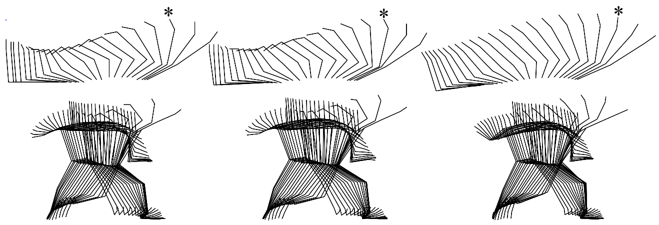
It is well known, in general, that the joint movements occur with the sequential pattern from the proximal segment to distal segment of the body (P-D sequence) in ballistic movements such as kicking, jumping, and throwing. In vertical jump, the hip extensors became active first, and are successively followed by the knee extensors and the ankle extensors. The similar results were reported in the throwing motions [1]. However, it is considered that the effect of the difference in ball mass on P-D sequence is still open to question. The purpose of this study is to clarify the change of throwing motion due to a change in ball mass.

METHODS

Two kinds of analytical techniques for throwing motion were used in this study; motion capture and computer simulation. Five male subjects volunteered as subjects. In the motion capture experiment, they were asked to throw many kinds of ball; three kinds of baseball (mass: 0.120, 0.145, 0.170 kg, circumference: 0.23 m), three kinds of softball (mass: 0.150, 0.190, 0.220 kg, circumference: 0.30 m), and a handball (mass: 0.450 kg, circumference: 0.59 m). Three dimensional coordinate of the subjects, including the coordinate of index finger and long finger, were measured by a motion capture system (VICON MX+, 250 Hz). The throwing motions of the five subjects were normalized to create a standard motion (an averaged motion [2]) for each ball condition. In addition, the computer simulation of throwing motion was carried out with the three different ball mass conditions: normal baseball (0.145 kg), virtual baseballs (0.345 and 0.545 kg). The linked segment model with torque generators [3] was applied for the simulations. The ball was attached at MP joint of the middle finger. The object function for motion optimization in computer simulation was set as a weighted sum of a ball speed, a ball control, and passive joint torques, the last factor of which were negative and penalty factors due to the range of motion and degree of freedom. The genetic algorithm was used for the optimization in order not to reach the local maximum.

RESULTS AND DISCUSSION

Figure 1 shows the stick pictures of the standard motions for the three conditions; baseball (0.120 kg), softball (0.220 kg), and handball (0.450 kg). The forward movement of elbow joint, which was generated mainly by the horizontal adduction of shoulder, occurred earlier with the increasing the ball mass. The elbow angle at the ball release for handball was larger than baseball and softball.



(a) Baseball (b) Softball (c) Handball

Figure 1: Standard motion of throwing arm (hand, forearm, and upper arm) and whole body for three conditions: baseball 0.120 kg, softball 0.220 kg, and handball 0.450 kg. Time intervals are 0.008 s for throwing arm and 0.020 s for whole body. '*' indicates the ball release.

Figure 2 shows the resultant speeds of the ball, MP of middle finger, wrist, elbow, and shoulder. The peak speeds of ball, MP, and wrist decreased with the increasing the ball mass. In addition, the speed drops of ball, MP, wrist during the cocking phase (around 0.5-0.7 s) was unapparent for the handball.

It is inferred, from the experimental results above, that the three dimensional whip-like movement had been unapparent with the increasing the ball mass, although the P-D sequence was kept under the different ball mass conditions.

Figure 3 shows the stick pictures of simulated throwing. The forward movement of elbow joint occurred earlier with the increasing the ball mass, which was consistent with the experimental results.

Figure 4 shows the active states of the torque generators of shoulder and elbow. Although the basic patterns of active state were similar to each other, the timing of onset for shoulder horizontal adduction, shoulder internal rotation, and elbow extension were shifted earlier with the increasing the ball mass. On the other hand, the end timing of activation for the elbow extension was almost same for the three conditions. It is considered that the contribution of elbow extension had been larger in the larger mass condition than the normal condition.

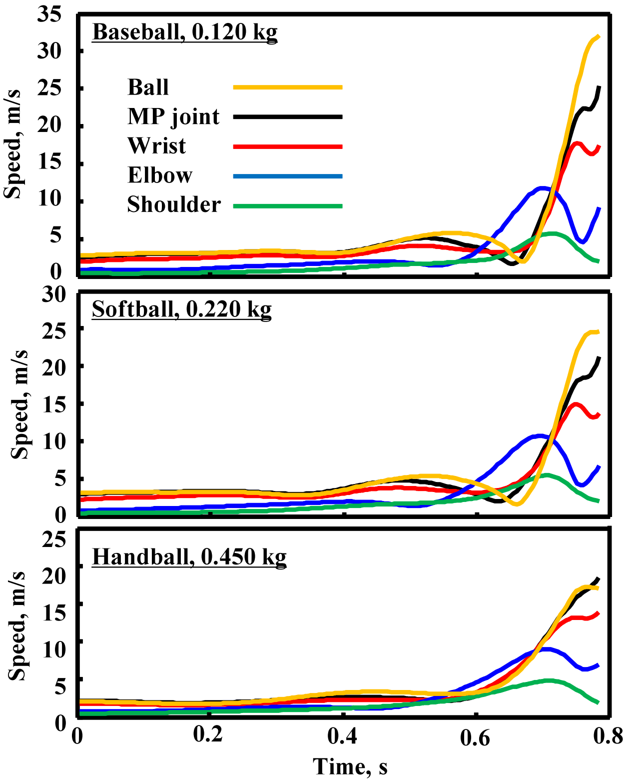
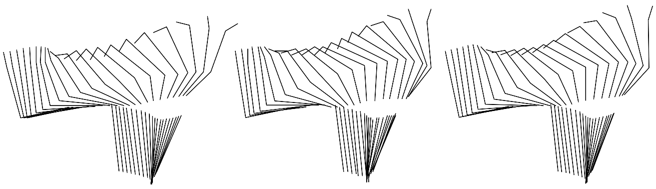


Figure 2: Resultant speeds of ball, MP of middle finger, wrist, elbow, and shoulder for three conditions: baseball 0.120 kg, softball 0.220 kg, and handball 0.450 kg.



(a) Normal (b) Virtual, 0.345 g (c) Virtual, 0.545 g

Figure 3: Stick pictures of simulated throwing motions. Time intervals are 0.005 s. Stick picture consist of hand, forearm, upper arm, and upper torso.

From the results of both the experimental analysis and computer simulation, it is considered that the contribution of the elbow joint had become larger and the contribution of shoulder joint had become less with the increasing the ball mass. Furthermore, it is also inferred that the subjects changed their motion patterns from the shoulder-dominant throwing to the elbow-dominant throwing under the larger ball mass condition since the rapid internal rotation (angular acceleration) of shoulder with heavier ball had enlarged the passive joint torques of elbow around varus-valgus axis, which might be the one of factors on the overuse injury. The other possible factor for the change of dominant joint was considered as to maximize the power generation which was related ball speed. Since the Hill-type torque generators (joint angle-torque, and joint angular velocity-torque relationships) were modeled and implemented into the simulation model, the coincident results between the experiment and the simulation might be observed.

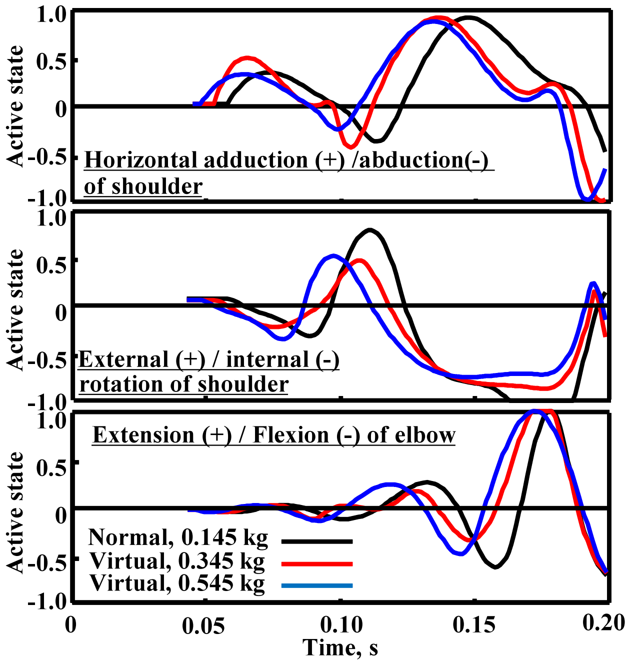


Figure 4: Active states of torque generators obtained by the simulated throwing motions. A torque generator behaves the antagonistic torque generators with the positive and the negative active states.

CONCLUSIONS

In this study, the effect of the difference in ball mass on P-D sequence was investigated. As the conclusion, it was inferred that the contribution of the elbow joint had become larger and the contribution of shoulder joint had become less with the increasing the ball mass. The further research is needed under the same circumference condition and the same surface condition of ball.

REFERENCES

1. Alexander RM, *J. Theoretical Biology*, **150**: 349-372, 1991.
2. Ae M, et al., *Bull Inst Health and Sport Sciences, Univ of Tsukuba*. **30**: 5-12, 2007.
3. Fujii N and Hubbard M, *J. Applied Biomechanics.* **18**: 135-154, 2002.