A THREE-DIMENSIONAL ANALYSIS OF HAND-ROLLING IN KAYAKING

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INTRODUCTION

The hand-rolling is one of the techniques for a capsized paddler to restore the vessel to the original state, by using the hands without the paddle. This hand-rolling is frequently used by paddlers of the canoe-polo players. Kinematics of the hand-roll movement that starts from under the water and ends above the water was investigated by using three-dimensional analysis.

METHODS

Three males and one female canoe-polo players (mean age 29.0±11.3 year, mean height 167.7±3.6 cm, mean weight 62.4±9.2 kg) participated in this study as subjects. Subjects were required to perform the hand-rolling with their hands, starting from a trunk position perpendicular to the water surface under their inverted kayak. Four digital video cameras (60 f/s, exposure time 1/250 s) were used: two cameras were set on the walkway of swimming pool for recording the motion above the water, and two others were for the motion under the water. Three-dimensional coordinates of segment end points under and above the water were first computed separately, and then combined as a coordinate data set. Angular kinematics of the upper limb segments was computed. The restitution angle of the kayak was defined as the angle between the perpendicular vector to the longitudinal axis of the kayak and the spatial vertical direction. Based on the restitution the hand–rolling movement was divided into; starting phase was from 180 to 135 degrees, middle phase was from 135 to 45 degrees, and final phase was from 45 to 0 degrees.

RESULTS AND DISCUSSION

Figure 1 and 2 show angular displacement for the right upper arm of the non-skilled subject for the skilled subjects. Comparing their movement of the upper arm, the elbow joint was abruptly extended in the non-skilled subject while it was gradually extended in the skilled subjects during the starting phase. For the shoulder joint, non-skilled

![Fig.1 Angular displacement of upper arm (Non-skilled subject)](image_url)
subject adducted under the water, but skilled subjects abducted horizontal in the starting and the middle phases.

Figure 3 shows angular displacement of the lateral tilt of the trunk. Smaller angle than 90deg. means the right side tilt and the bigger than 90deg. is the left side tilt. In the skilled subject, the trunk tilted left in the starting and middle phases, followed by tilting to the right side and a gradual backward lean. The left side tilt of the trunk for the skilled subjects in the starting phase resulted in the raising of the trunk to the surface of the water by the reaction from water. The right side tilt of the trunk in the middle phase may result from the moment generated by the restitution of the kayak rather than active trunk tilting. To rotate the vessel effectively for restitution, it will be helpful that the moment of inertia of the system is small in middle and final phases by tilting the trunk to bring it close to the axis of rotation. The backward lean can reduce the moment of inertia of the system, about the longitudinal axis of the kayak.
Figure 4 shows the hand position in the starting phase for three subjects, which was the backward view of the subjects. Roll movement of subject RY started to stroke with a single hand, left hand first (the upper figure) and right hand next (the lower figure). Two skilled subjects showed longer moment arm from the hand position to the center of the kayak to increase the moment of force.

In summary, the starting phase is the phase to get the moment of force to rotate the kayak by setting the hands far from the axis of rotation and by pushing the water downward. The middle phase is the phase to use the angular momentum earned during the starting phase and to rotate the kayak with tilting the trunk. The final phase is the phase to set the trunk upright position to the kayak with moving the trunk to the direction of rotation and forward.

REFERENCES