CHANGE IN KINETICS OF THROWING ARM JOINTS IN ELEMENTARY SCHOOL CHILDREN DUE TO TRAINING OF A DISTANCE THROW

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The purpose of this study was to investigate effects of training with a standard motion model on the kinetics of throwing arm joints in elementary school children. Thirty-two children from sixth grade were participated in three sessions: pre- and post-training videotaping and technique training. Their throwing motions were videotaped with two high-speed cameras and analysed three-dimensionally. Through the training with the use of standard motion model as a reference, throwing distance and ball velocity significantly improved. Joint force, joint torque and mechanical work in throwing arm joints increased at the post-training. The results indicated that the use of standard motion model was useful for the improvement in throwing distance and joint kinetics of throwing arm.

KEY WORDS: delayed display, joint torque, mechanical work, standard motion.

INTRODUCTION: In a physical education class of Japanese elementary schools, one of the essential tasks in teaching is to help children understand and perform a good motion pattern to be learned. However, this approach has some limitations, e.g., there is motion variability in a model technique due to model persons' property, there is no firm or valid base for appropriate motion models, and so on.
We established standard motion models of overarm throwing as an averaged motion pattern of the skilled elementary children and found that the use of the motion model was useful for the improvement in the throwing distance and throwing techniques (Kobayashi, Ae, Miyazaki, & Fujii, 2012; Kobayashi, Ae, Miyazaki Fujii, & Iiboshi, 2014). However, changes in the kinetics resulted from the training has not investigated yet.
Investigation of the kinetics in the throwing arm joints can reveal factors for the improvement in performance, i.e., throwing distance and ball velocity, and provide useful information in designing appropriate teaching programmes for the throwing techniques of children. Therefore, the purpose of this study was to investigate effects of a training with the use of a standard motion model on the kinetics of the throwing arm joints in elementary school children.

METHODS: Seventeen boys (age, 12 yrs; height, 1.46 ± 0.07 m; weight, 39.62 ± 10.03 kg) and fifteen girls (age,12 yrs; height, 1.46 ± 0.06 m; weight, 38.35 ± 5.84 kg) from sixth grade of one Japanese elementary school participated in three sessions: the pre- and post-training videotaping and technique training. They were instructed to throw a softball (8.5 cm in diameter; 141 g in mass) twice with their maximal effort in physical education lessons, according to the procedure of the Japan Fitness Test regulated by the Japanese Ministry of Education, Culture, Sports, Science and Technology. The regulation specifies the ball size and weight, and prescribes that one longer throw of two trials be adopted as a best performance. The throwing motion of the subjects was videotaped in the pre- and post-training for comparison with two high-speed digital cameras (Exilim EX-F1, Casio Co., Japan) operating at 300 Hz, which were synchronized by a light-emitting diode synchronizer (DKH Co., Japan).
The subjects participated in the technique training once a week, 45 minutes a day, for three weeks. The first part of the training consisted of instruction on the standard motion model explained by the investigators (Figure 1a), and observation of children's own throwing motion by using a delayed display system (Figure 1b, c). The second part included several throws of

a softball toward the ground and/or the wall, throws from a run-up and throws for distance, totally about 30 times for each subject. In the technique training, the standard motion models established by Kobayashi et al. (2012) were used as a reference, which were the normalized and averaged motion pattern of seven skilled boys and girls of sixth grade.

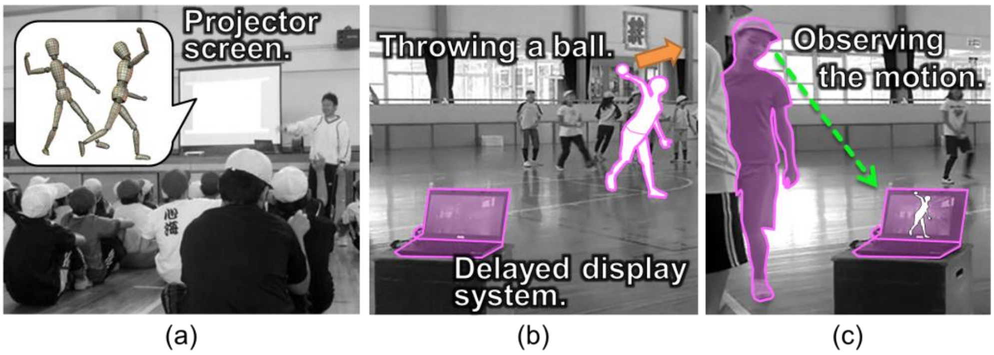

Figure 1. Flow of the technique training.

Based on the change in the throwing distance due to the training, a typical thrower (girl; height, 1.46 m; weight, 39.5 kg) was selected for the analysis of effects of the technique training. Twenty-three body landmarks and the centre of a softball were digitized with a digitizing system (Frame-DIASⅡ, DKH Co., Japan). Three-dimension coordinate data were reconstructed by the DLT method and were smoothed by a Butterworth digital filter with cut-off frequencies ranging from 7.5 to 12.5 Hz decided by the residual method described in Winter (2009).

The height, velocity, and release angle of the ball at time of release and kinematic data were obtained from three-dimensional coordinate data. The joint velocity and joint angular velocity were calculated as time-derivatives of displacements of joint position and joint angle, respectively. The location of the centre of mass, the mass and the moment of inertia for the subjects' body segments were estimated according to the Japanese children's body segment parameters after Yokoi, Shibukawa, & Ae (1986).

The joint forces and torques at the wrist, elbow, and shoulder of the throwing arm were obtained by solving the equations of motion from the distal to the proximal segments. Joint force power (JFP) was calculated as an inner product of the joint force and joint velocity, and joint torque power (JTP) was calculated as an inner product of the joint torque and joint angular velocity.

The mechanical energy of the upper arm, forearm and hand segment was calculated as the sum of the potential, translational and rotational energies of the segment. The segment mechanical power was a time-derivative of the segment mechanical energy.

The mechanical power of the throwing arm was divided into five mechanical powers (Figure 2): (1) JFP of the shoulder, (2) Trunk-shoulder torque power, (3) JTP of the shoulder, (4) JTP of the elbow, (5) JTP of the wrist. The trunk-shoulder torque power (TSTP) was calculated as an inner product of the shoulder joint torque and angular velocity of the trunk, which indicated mechanical energy flow from the trunk to the upper arm by the shoulder joint torque. The mechanical work done in the throwing phase was calculated as a numerically integration of the five mechanical powers. Time-series data, such as joint angular velocity and joint torque, were normalised by the time of a throwing phase, which was defined as spanning from the instant of stride-foot contact to the instant of ball release.

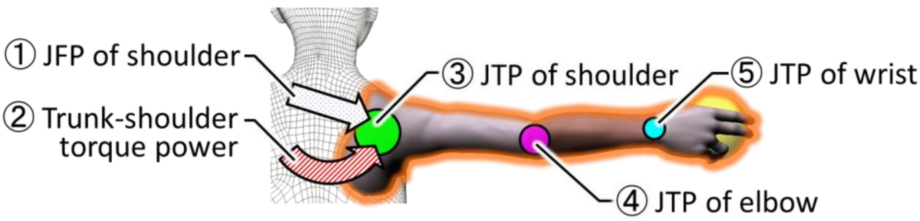

Figure 2. Conceptual diagram of the five mechanical powers in the throwing arm.

Paired *t*-test was used to test differences between the pre- and post-training with the significance level set at 5%.

RESULTS: The throwing distance at the post-training was significantly larger than that of the pre-training (boys, pre-training 29.1±7.9 m, post-training 32.7±9.8 m; girls, pre-training 16.0±4.1 m, post-training 17.0±3.3 m, $p<0.05$). The ball velocity at the post-training was significantly faster than that of the pre-training (boys, pre-training 18.5±3.4 m/s, post-training 19.5±3.9 m/s; girls, pre-training 12.5±2.0 m/s, post-training 13.2±1.5 m, $p<0.05$). The throwing distance, ball velocity, release angle and height of subject A as a typical one at the post-training were greater than those of the pre-training (pre- and post-training; throwing distance 10.0 and 13.5 m; ball velocity 9.0 and 11.3 m/s; release angle 28.4 and 29.9 degree; release height 1.73 and 1.78 m).
Figure 3 show the change in trunk rotation angle of the subject A at the pre- and post-training and the standard motion model for girls. The trunk forward rotation before ball release became larger at the post-training, and its pattern was closer to that of standard motion model.
As shown in Table 1, the peak joint torque and force of the shoulder and the peak joint torque of the elbow increased after the technique training.
Figure 4 show the mechanical works due to the five mechanical powers for subject A. The total mechanical work of the throwing arm after the training was larger than the pre-training. The JFP of the shoulder, TSTP and JTP of the shoulder were larger than those of the pre-training. The ratio of TSTP to the total mechanical work of the throwing arm increased 21 percent due to the technique training.

DISCUSSION: The mechanical energy flow was found from the proximal to the distal segments toward ball release, as Jöris, van Muyen, van Ingen Schenau, & Kemper (1985) pointed out in the female's handball throwing. Therefore, the increase in the mechanical work of the throwing arm at the post-training contributed to the increase in the mechanical energy of ball at ball release and then improvement in the throwing distance.

Table 1. Peak joint torques of shoulder abduction, shoulder horizontal adduction and shoulder internal rotation and elbow extension and peak joint force of the shoulder at the pre- and post- training for subject A.

	Pre	Post
Peak shoulder abduction torque [Nm]	6.2	7.0
Peak shoulder horizontal adduction torque [Nm]	11.2	14.0
Peak shoulder internal rotation torque [Nm]	9.2	12.0
Peak elbow torque [Nm]	4.5	6.8
Peak shoulder joint force [N]	64.1	104.3

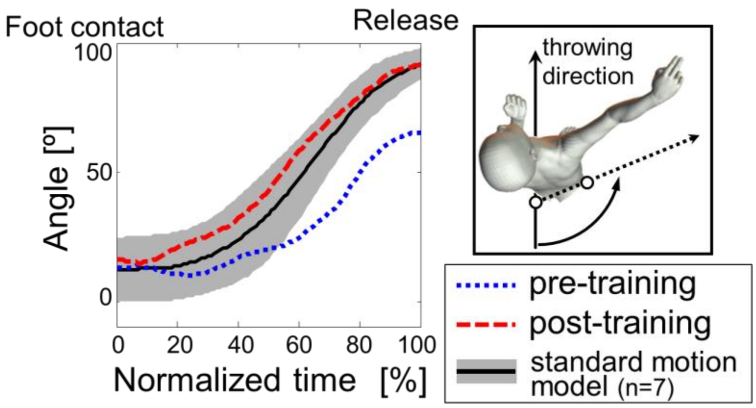

Figure 3. The lower trunk rotation angle in the pre- and post-training for subject A. Black solid line and shaded area indicate averaged angle and range of one standard deviation.

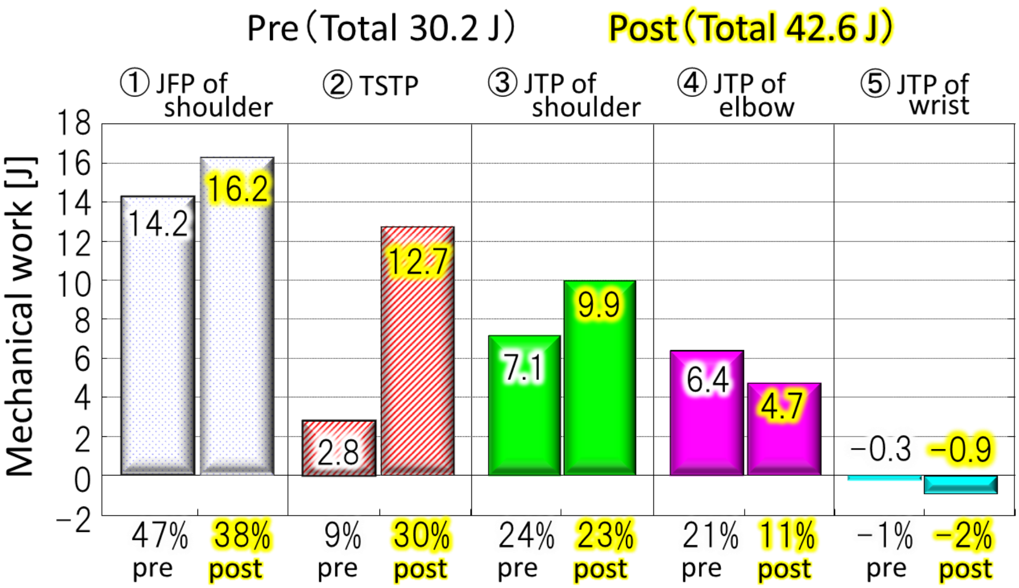

Figure 4. Mechanical works in the throwing phase due to the five mechanical powers of throwing arm for subject A. The percent value indicates the ratio to the total mechanical work of the throwing arm in pre- and post-training.

The increased work by JTP of the shoulder at the post-training can be attributed to the improvement in the shoulder joint torque (Table 1). The work by JFP of the shoulder was largest in the five mechanical powers in the throwing arm, and the work by TSTP markedly increased at the post-training (Figure 4). These indicate that the subject A was able to generate more mechanical energy in the shoulder joint and flow the large mechanical energy from the trunk to the throwing arm by using the joint force and torque of the shoulder after the technique training.

The large increase in the work by TSTP was resulted from the increase in the shoulder joint torque and an angular velocity of the trunk forward rotation. It is inferred from Figure 3 that the subject A would be aware of difference between her own throwing motion and the standard motion model by comparison, and try to change her motion through visual feedback and throwing drills in the training.

These revealed that the use of the standard motion model as a reference in teaching was useful to correct throwing motion and change the kinetics of the throwing arm joints for appropriate one.

CONCLUSIONS: Through the technique training of the distance overarm throw, the throwing distance and release parameters were improved in the elementary school children. The joint force, joint torque and mechanical work in the throwing arm joints increased due to the technique training. The results indicated that the use of the standard motion model was useful for the improvement in the kinetics of the throwing arm joints.

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