Portuguese Journal of Sport Sciences
11 (Suppl. 2), 2011

DEVELOPMENT OF THE OVERARM THROWING MOTION FOR JAPANESE ELEMENTARY SCHOOL GIRLS

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The purpose of this study were to investigate characteristics of the overarm throwing motion for Japanese school girls, 2nd, 4th and 6th grades, with a standard motion model of skilled girls. The throwing motions of fifty-one girls were videotaped and seven girls for each grade were selected based on the throwing distance for 3-D motion analysis. Throwing distance, ball velocity and release height were significantly increased with the increase in school grades. The 2nd grade girls threw by a dominant shoulder joint abduction and elbow joint extension, the 4th grade girls indicated a large range of motion of the right upper limb, and the 6th grade girls strode forward with the trunk leaned to the right and used a rapid external-internal rotation of the shoulder joint.

KEY WORDS: development, children, overarm throwing, standard motion.

INTRODUCTION: In physical education class of elementary schools, teachers will first observe the performance and motion of children to identify his or her technical faults. Then, teachers will attempt to correct their faults and improve their performance through appropriate lessons, practice and training. The essential but most difficult step in these teaching processes is the evaluation and diagnosis of techniques. One of the methods for evaluating techniques of children is comparison of the children's motion with some models for which some motion patterns of adults or certain skilled children motion patterns have been frequently employed. But there is no firm or valid base for appropriate motion models. If teachers have no concrete ideas to evaluate children's motion, it is difficult to make appropriate decisions. For a better technique teaching, we need prepare some appropriate motion models of sports techniques. There are some studies on motion model and technique analysis method for adults and athletes (Ae et al., 2007), but there is less information of motion model, especially throwing motion for children. Nelson et al. (1991) investigated longitudinal changes in children's throwing performance from a viewpoint of gender differences and found that girls had more difficulties to improve throwing motion than boys since the developmental level of girl's movement pattern indicated little changes from 5 to 8 years old. These results denote the necessity for establishing appropriate motion models to teach girls effectively. Therefore, the purpose of this study was to investigate kinematic characteristics of the overarm throwing for Japanese elementary school girls with a standard motion model of skilled girls.

METHODS: Data Collection: Fifty-one girls of elementary school (2nd, 4th and 6th grade) participated in this study. They were asked to throw a softball (diameter: 8.5 cm, mass: 141 g) with maximal effort according to the procedure of the Japan Fitness Test regulated by the Ministry of Education, Culture, Sports, Science and Technology, where the ball size is specified. The throwing motion was videotaped with three digital movie cameras (Exilim EX-F1, CASIO Co., Japan) operating at 300 Hz. Based on their throwing distance, seven girls for each grade (2nd grade: 1.21±0.04 m, 23.71±3.06 kg, 4th grade: 1.35±0.05 m, 29.04±3.88 kg, 6th grade: 1.45±0.05 m, 35.90±5.96 kg) were selected as good throwers for detailed three-dimensional motion analysis and one throwing motion with the best performance for each selected subject was analyzed. All selected subjects were right-handed throwers.
Data Analysis: Twenty-three body landmarks and center of the softball were digitized at 150 Hz. Their three-dimensional coordinates data were reconstructed by a DLT method and were smoothed by a Butterworth digital filter at cutoff frequencies ranging from 7.5 to 12.5 Hz, which were decided by a residual method. Standard motion proposed by Ae et al. (2007) was

established from coordinates data of seven subjects for each grade. The primary variables computed were velocity, height and release angle of the ball at the release, kinematics of the upper and lower limb joints and trunk. The throwing motion was divided into striding and throwing phases. The striding phase was defined as the phase from the lowest ball height to the stride foot contact and the throwing phase was the phase from the stride foot contact to the ball release. Kinematic data were normalized as 100% time for each phase, totally 200% time (average time of all groups was 0.36s for the striding phase and 0.28s for the throwing phase), and then averaged every 1% time. The ANOVA was used to test the effects of grades on variables computed, followed by a multiple comparison, Scheffe's method, to evaluate differences between grades. The level of significance was set at 5%.

RESULTS: Table 1 shows throwing distance, ball velocity, release angle and release height for girls of three grades. Throwing distance and ball velocity significantly increased with the increase in school grades ($p<0.05$). Although no significant difference in release angle was found between grades, standard deviation of release angle tended to be smaller as the grade proceeded. Release height of the 2nd grade was significantly smaller than that of the other two grades ($p<0.05$).

Table 1
Throwing distance, ball velocity, release angle and release height for girls of three grades

	Throwing distance [m]		Ball velocity [m/s]		Release angle [deg]		Release height [m]	
Grade 2	8.21±1.79	*	10.19±1.69	*	22.0±13.9		1.35±0.06	*
Grade 4	14.70±2.18	*	13.50±0.64	*	26.9±9.4	n.s.	1.54±0.10	*
Grade 6	21.24±4.14	*	15.91±1.54	*	31.7±6.9		1.60±0.09	

*p<0.05

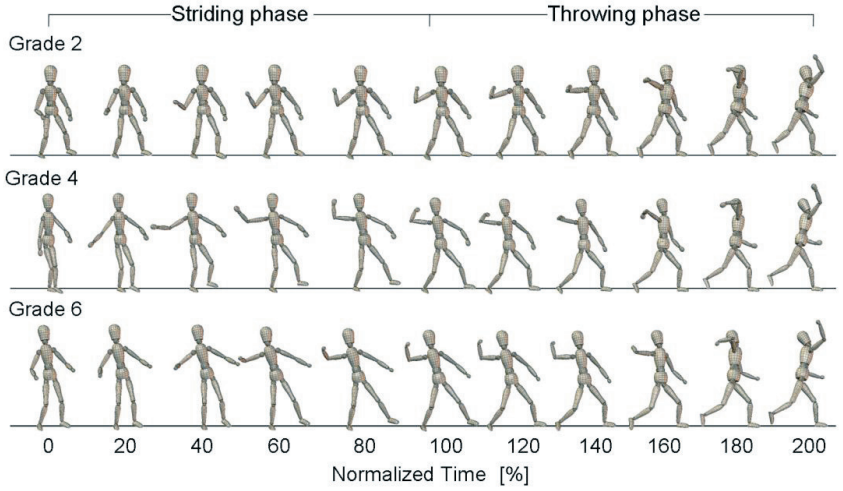

Figure 1: Standard motion of the overarm throwing for the skilled girls.

Figure 1 shows standard motions of the overarm throwing for girls of the three grades, which were drawn every 20% time from the lowest ball height to release. The trunk of the 2nd grade girls was more erected in almost the whole phase and that of the 6th grade girls

largely leaned rightward around the stride foot contact (100% time). No remarkable differences were found in motion on the left upper limb between grades. However, motion of the right upper limb showed some differences, such that the elbow joint of the 2nd grade was low and more flexed during the striding phase (see 40 to 100% time).

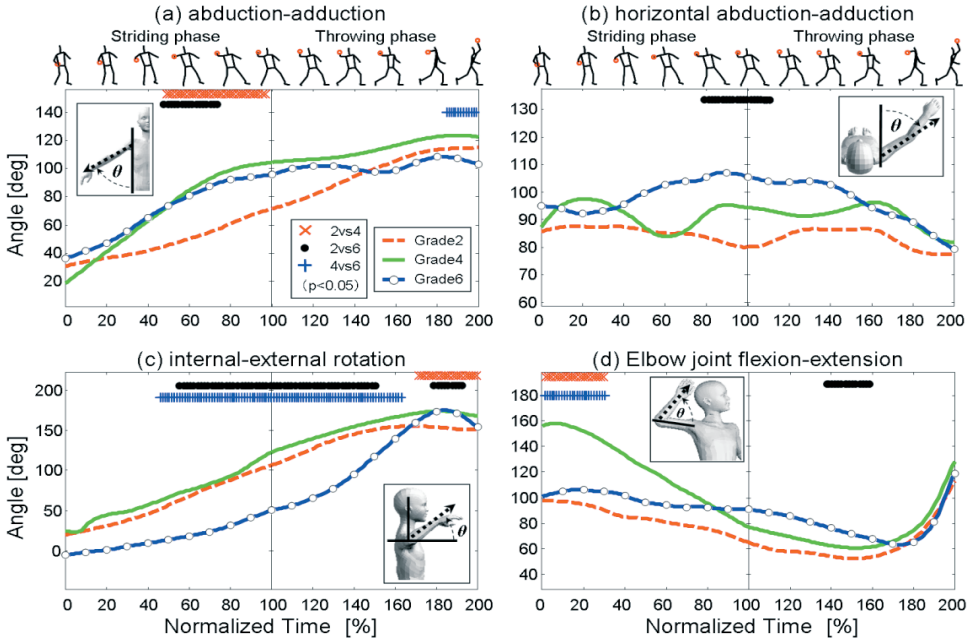

Figure 2: Averaged patterns of changes in the joint angles of the throwing arm for the skilled girls. The small X, circles and cross marks shown in the upper area indicate significant differences, (×) on 2vs4, (●) on 2vs6, (+) on 4vs6. The average time of all groups was 0.36s for the striding phase and 0.28s for the throwing phase.

Figure 2(a) shows change in the abduction-adduction angle of the right shoulder joint. In the 2nd grade girls, abduction angle of the shoulder joint was significantly smaller than the other two grades during the second half of the striding phase, although it increased until the release. The 4th and 6th grade girls largely abducted in the two-thirds period of the striding phase, but no remarkable change was seen until the half part of the throwing phase. But the 6th grade girls' abduction angle did not greatly increase in the throwing phase and was significantly smaller than the 4th grade before the release. Figure 2(b) shows change in the horizontal abduction-adduction angle of the right shoulder joint. The horizontal abduction angle of the 2nd grade girls was smaller than 90°. In the 6th grade girls, the horizontal abduction angle was significantly larger than the 2nd grade girls around the stride foot contact. Figure 2(c) shows changes in the internal-external rotation angle of the right shoulder joint. From the second half of the striding phase to the first half of the throwing phase, the external rotation angle was significantly smaller in the 6th grade girls than in other two grades. However, the 6th grade girls quickly rotated shoulder joint externally from approximately 140% time and reached its peak just before release, and then internally rotated the shoulder joint until the release. Although the 2nd and 4th grade girls externally rotated the shoulder joint continuously until the middle of the throwing phase, no quick external and internal rotation like the 6th grade occurred just before the release. Figure 2(d) shows changes in the flexion-extension angle of the right elbow joint. Compared to the other grades, the 4th grade girls largely extended the elbow in the first half of the striding phase. In the middle part of the throwing phase, the elbow angle of the 2nd grade girls was significantly

smaller than the 6th grade girls, indicating the elbow joint of the 6th grade girls were more extended than the 2nd grade girls.

DISCUSSION: Significant differences observed in Table1 indicated that the most effective parameter on throwing distance was the ball velocity. In the striding phase, the 2nd grade girls slightly abducted the shoulder joint and greatly flexed the elbow joint. Then, the shoulder joint was abducted at constant angular velocity toward the release and the elbow joint was moderately extended after the midpoint of the throwing phase. The 6th grade girls were striding with the trunk leaned to the right and greatly abducted and slightly external rotated shoulder joint. Then, they were throwing with a rapid external and internal rotation of the shoulder joint. Although the 4th grade girls abducted the shoulder joint in similar manner to the 6th grade, change in external rotation angle of the shoulder joint for the 4th grade girls was similar to that of the 2nd grade girls. Furthermore, in the first half of the striding phase, elbow joint of the 4th grade girls was remarkably extended. These results indicate that the throwing motion was characterized by a dominant shoulder abduction and elbow extension for the 2nd grade girls, by a large range of motion of the upper limb for the 4th grade girls, by a rapid external-internal rotation of the shoulder for the 6th grade girls. Sekine et al. (1999) indicated that the increase in the range of motion for boys within average throwing distance resulted from the increased range of motion in lower limb and trunk with the increase in school grades. In the present study, increase in the range of motion occurred in the upper limb rather than the lower limb. This would be one of the characteristics of development of girl's throwing motion. It was assumed that handling and overarm throwing a ball was a difficult task for the immature 2nd grade girls. This difficulty may be one the reasons of their retarded preparation of the throwing arm. On the other hand, the data of the 6th grade girls may indicate that the preparative motion to throw a ball was well established in the age, which would help an effective use of strech-shortening cycle of the shouder muscles. Leme & Shambes (1978) revealed that adult women subjects who threw with slow ball velocity exhibited immature throwing patterns which were directly analogous to the more primitive so-called "stages" previously identified in young children. In addition, pictures of motion patterns for stage 6 and stage 7 described by Leme & Shambe are similar to the 4th and 6th grade girls. Our results revealed some characteristics and development of throwing motion for Japanese elementary school girls. Although we could not observe the differences in the leg, some changes will occur in lower limb and trunk just like boys as girls acquire more experience of overarm throwing.

CONCLUSION: The ball velocity was significantly increased with the increase in school grades and showed the greatest effect on the difference of the throwing distance between grades. Standard motion exhibited some differences in the throwing motion among grades, and the range of motion occurred in the right upper limb increased as the grade proceeded. The 2nd grade girls threw by a dominant shoulder joint abduction and elbow joint extension, the 4th grade girls indicated a large range of motion of the right upper limb, and the 6th grade girls strode forward with the trunk leaned to the right and used a rapid external-internal rotation of the shoulder joint.

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