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Angular Momentum in Skilled Kicking Pullover Performed by Elementary School Children

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ABSTRACT

Topics in Exercise Science and Kinesiology Volume 3: Issue 1, Article 2, 2022. This study aimed to clarify the differences in body positions and the role of the swing leg, support leg, and head-arm-trunk segment in generating and maintaining angular momentum of the whole body about a horizontal bar as well as how to improve the skill level of successful kicking pullover attempts. Two-dimensional kinematic parameters of successful kicking pullover attempts and body composition indices of 26 fifth-grade elementary school children were collected. Their techniques were classified into excellent and good groups based on the subjective evaluation of three evaluators. Although there were no significant differences in body composition indices between the two groups, the motion phase time during the 4th phase and the total time of the excellent group were significantly shorter compared with the good group. Also, the counterclockwise rotation of the angular momentum of the head-arm-trunk segment and the whole body during the 4th phase was significantly larger in the excellent group than in the good group. These results suggest that maintaining the angular momentum of the head-arm-trunk segment during the 4th phase leads to attempts with shorter time and improves skill levels from the good group to the excellent group. The good group was not able to maintain angular momentum of the whole body during the 4th phase because the peak of the angular momentum of the head-arm-trunk segment and support leg tended to appear earlier than in the excellent group. we newly clarified that teachers need to focus on the body position of the trunk and head during the 4th phase in order for elementary school children to succeed in kicking pullovers more beautifully at a higher level.

KEY WORDS: Biomechanics, physical education, motion analysis, horizontal bar, gymnastics

INTRODUCTION

Gymnastics is a sport in which competition is judged based on both the difficulty and beauty of techniques. In Japan, the Ministry of Education, Culture, Sports, Science and Technology [1] requires Japanese elementary schools to teach children at least one of the following gymnastic exercises: floor, horizontal bar, or vaulting horse. Although there are many kinds of techniques involved in these three exercises, the kicking pullover (also known as forward upward circling) on the horizontal bar is one of the standard techniques taught in Japanese physical education classes. Hayashi et al. [2] reported that elementary school children who were not able to achieve the kicking pullover were likely to develop a dislike of physical activities. Thus, elementary school teachers need to be able to appropriately explain how to perform the kicking pullover and help children achieve the technique.

Some previous studies on the kicking pullover have clarified how to successfully perform the technique through kinematic analysis comparing successful versus unsuccessful attempts [3,4,5] as well as kinetic analysis of successful attempts [6,7]. Those findings indicate that to successfully perform the kicking pullover technique, it is necessary to generate a large angular momentum of the whole body by 1) the swinging motion of the swing leg, 2) stepping of the support leg (exerting a ground reaction force), and 3) leaning the trunk backward.

Generally, most elementary school children have not had gymnastics training, and thus teachers in elementary physical education classes need to help children successfully achieve the kicking pullover technique. Therefore, the findings of these previous studies obtained by comparing successful and unsuccessful attempts and analyzing the successful attempts seem to be useful. However, the purpose of these physical education classes is not only to achieve a successful attempt but also to perform more artistic and beautiful movements. In fact, even if children can achieve some of the techniques successfully, the level of proficiency varies from 'a barely achieved attempt' to 'an outstanding attempt.' Therefore, physical education teachers need to teach children not only to successfully achieve the technique but also to perform it using more artistic and beautiful movements. The current commentary on Japanese government educational guidelines of physical education requires children to continue practicing so as to perform the technique more magnificently and beautifully after successfully achieving it, and points out the importance of addressing problems according to the abilities of each learner [1].

From the above, it is also very important to determine how to improve the performance of the technique that has already been successfully achieved. Shimizu et al. [8] conducted a study from this perspective, classifying the kicking pullover attempts of 52 fifth-grade elementary school children into four groups and clarifying the kinematic characteristics according to skill level by constructing and comparing averaged motion models of the technique. The results showed that the maximum angular velocity of the swing leg in the 'outstanding' model was large, whereas that of the support leg in an 'executed' model appeared earlier compared with the outstanding model, and the trunk was not raised in a short period from the upside-down posture. However, they did not investigate the extent to which differences in movements between the two groups affected the generation and maintenance of angular momentum of the whole body. Although Konosu et al. [7] evaluated angular momentum of the whole body about the center of mass (CoM), angular momentum of the whole body should be analyzed about the horizontal bar because the body must rotate around the horizontal bar axis to perform the kicking pullover technique. Additionally, the role of the swing leg, support leg, and the head-arm-trunk (HAT) segment in generating and maintaining angular momentum of the whole body remains to be clarified. By clarifying these angular momenta, it might be possible to clarify the coordination of the swing leg, support leg, and HAT segment required to improve the skill level involved in successful attempts.

Therefore, this study aimed to clarify the differences in body positions and the role of the swing leg, support leg, and HAT segment in generating and maintaining angular momentum of the whole body about the horizontal bar as well as how to improve the skill level of successful kicking pullover attempts.

METHODS

Data Collection

Kicking pullover attempts were performed during the physical education class by 52 fifth-grade elementary school children (age: 10-11 years). Before any data were collected, the nature of this study was explained to the principal of the elementary school, the physical education teacher, and the children, and informed consent to participate in the study was obtained from all subjects. We explained that participation in this study was voluntary, consent to participate could be withdrawn at any time, and no disadvantage was incurred if consent to participate in the study was not given. The study was approved by the ethics committee of the corresponding author's institution (approval number 4) and was conducted in accordance with the principles of the Declaration of Helsinki.

Subjects in this study were selected only 26 children (males = 13, females = 13) who could successfully perform the kicking pullover technique. Although all subjects performed two trials, one trial with a higher score was analyzed. The skill levels of all successful attempts were evaluated and divided into two groups by the mean score of 5-grade evaluations (5 means 'very good') by three subjective evaluators, including one university faculty lecturer and two university students.

Body height, body mass, skeletal muscle mass, body fat percentage, skeletal muscle index, and Kaup Index were measured as body composition indices by using a body height scale and body composition meter (InBody 470, InBody Japan K.K.). In addition, grip strength was measured twice each on the left and right sides by using an analog grip dynamometer (TKK5001, Toei Light Co., Ltd.), and the means of the left and right measurements were used in the analysis.

Table 1 shows the skill level score, the body composition indices and the grip strength of all subjects. Of the 26 successful kicking pullover attempts, 13 were classified as an 'outstanding attempt' (12 points or more, males = 7, females = 6) and 13 as an 'executed attempt' (11 points or less, males = 6, females = 7) according to the total score of the subjective of three evaluators. The reliability of the evaluation was confirmed because there were no significant differences among the three evaluators (intraclass correlation coefficient = 0.770). Therefore, we named the two groups as 'excellent group (outstanding attempt)' and 'good group (executed attempt).'

The children were instructed to perform the kicking pullover technique on a low horizontal bar in the gymnasium of the elementary school. Three heights (1.05, 1.10, and 1.15 m) were set based on the distance from the chest to the shoulder, and the children were allowed to select the height they preferred.

Table 1. The skill level score, body composition indices and grip strength of all successful attempts.

	ID	Sex	Evaluator A	Evaluator B	Evaluator C	Total score	Body height (cm)	Body mass (kg)	Skeltal muscle mass (kg)	Body fat percentage (%)	Skeltal muscle index	Kaup index	Grip strength (kg)
Excellent group (n=13)	Subj.1	female	4	5	4	13	142.4	30.9	24.1	16.8	4.2	15.2	13.5
	Subj.2	female	5	4	4	13	143.3	33.0	27.0	13.2	5.1	16.1	15.5
	Subj.3	male	5	4	4	13	132.1	32.1	23.9	21.2	4.9	18.4	11.5
	Subj.4	female	5	4	4	13	122.0	25.8	20.2	17.5	4.7	17.3	12.0
	Subj.5	female	5	4	4	13	128.5	26.6	21.6	13.9	4.5	16.1	13.0
	Subj.6	male	4	4	4	12	141.3	34.5	26.6	17.8	4.9	17.3	18.0
	Subj.7	female	4	4	4	12	135.4	28.9	23.0	15.6	4.5	15.8	14.0
	Subj.8	female	4	4	4	12	142.2	34.3	24.7	23.3	4.4	17.0	12.5
	Subj.9	male	4	4	4	12	146.4	38.3	30.6	15.2	5.6	17.9	17.0
	Subj.10	male	4	4	4	12	149.4	38.0	30.4	15.3	5.3	17.0	19.0
	Subj.11	male	4	4	4	12	132.1	34.6	24.8	24.0	5.3	19.8	18.0
	Subj.12	male	4	4	4	12	140.2	33.2	25.7	17.4	4.7	16.9	15.0
	Subj.13	male	4	4	4	12	144.6	36.2	29.2	14.4	5.6	17.3	17.0
Good group (n=13)	Subj.14	male	3	4	4	11	127.8	27.4	21.4	17.1	4.4	16.8	12.0
	Subj.15	male	3	4	4	11	129.1	24.5	20.6	11.1	4.4	14.7	12.5
	Subj.16	male	4	4	3	11	129.3	33.4	24.0	24.0	5.4	20.0	14.0
	Subj.17	male	3	4	4	11	142.6	34.3	26.8	17.1	4.9	16.9	17.0
	Subj.18	female	3	4	4	11	141.0	33.6	26.6	16.1	5.0	16.9	17.5
	Subj.19	female	3	4	4	11	152.2	55.8	39.1	25.5	6.7	24.1	23.5
	Subj.20	female	3	3	4	10	139.3	36.3	26.6	22.6	5.0	18.7	17.5
	Subj.21	male	2	4	4	10	146.4	33.6	28.8	9.1	5.3	15.7	17.5
	Subj.22	female	3	3	4	10	144.3	44.6	32.7	22.3	6.1	21.4	15.5
	Subj.23	female	4	3	3	10	143.2	32.6	24.2	21.1	4.2	15.9	16.5
	Subj.24	male	3	3	3	9	143.0	33.8	28.3	11.1	5.2	16.5	20.5
	Subj.25	female	2	3	3	8	147.3	38.8	28.7	21.3	5.2	17.9	18.0
	Subj.26	male	2	2	3	7	145.7	33.8	27.9	12.6	4.9	15.9	10.0
				Excellent group (n=13)		Mean	138.5	32.8	25.5	17.4	4.9	17.1	15.1
						S.D.	7.9	3.9	3.2	3.5	0.5	1.2	2.5
				Good group (n=13)		Mean	140.9	35.6	27.4	17.8	5.1	17.8	16.3
						S.D.	7.6	7.8	4.8	5.5	0.7	2.6	3.6
				Mann-Whitney Utest		|Z|	0.8	0.74	0.92	0.18	0.7	0.03	0.82
						p	0.43	0.46	0.36	0.86	0.49	0.98	0.41
						mark	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
						1-β	0.02	0.19	0.20	0.06	0.12	0.13	0.15

Evaluation: 5 means 'very good'

A high-speed camera (Exilim EX-F1, Casio Inc.) was used to record each attempt and was placed approximately 15 m from the horizontal bar so that analysis could be performed from a two-dimensional sagittal plane. The recording speed was set at 300 fps, and the exposure time was set at 1/500 s. Before the data collection was initiated, calibration poles (height: 2.50 m) with six markers at 0.5-m interval were placed in three spots (width: 2.00 m) at 1.00-m intervals. Calibration was carried out so that the real length conversion could be performed using the two-dimensional direct linear transformation method.

Data Processing

The collected video images were digitized at 100 Hz and converted to real length by using Frame-DIAS 5 (Q'sfix Inc.). Mean reconstruction errors were 0.20 cm on the X-coordinate and 0.40 cm on the Y-coordinate.

The motion analysis landmarks were the elbow joint, shoulder joint, toe, heel, ankle joint, knee joint, hip joint, head, ear, and the horizontal bar. Data were collected within the time constraints of the physical education class; therefore, markers could not be attached to each part of the body, and thus each part of the body was digitized manually from the video images. To ensure the accuracy of the digitization, the toes, heels, ankles, and knees on the left and right half sides and the elbows, shoulders, and hips on the camera side (right half) were digitized. In this study, three researchers with digitizing experience confirmed and corrected the accuracy of all digitizations.

After determining the optimal cut-off frequency (7.0–9.0 Hz), the two-dimensional coordinates obtained for each motion analysis point were smoothed using a 4th order Butterworth low-pass digital filter based on a residual analysis by the Winter method [9].

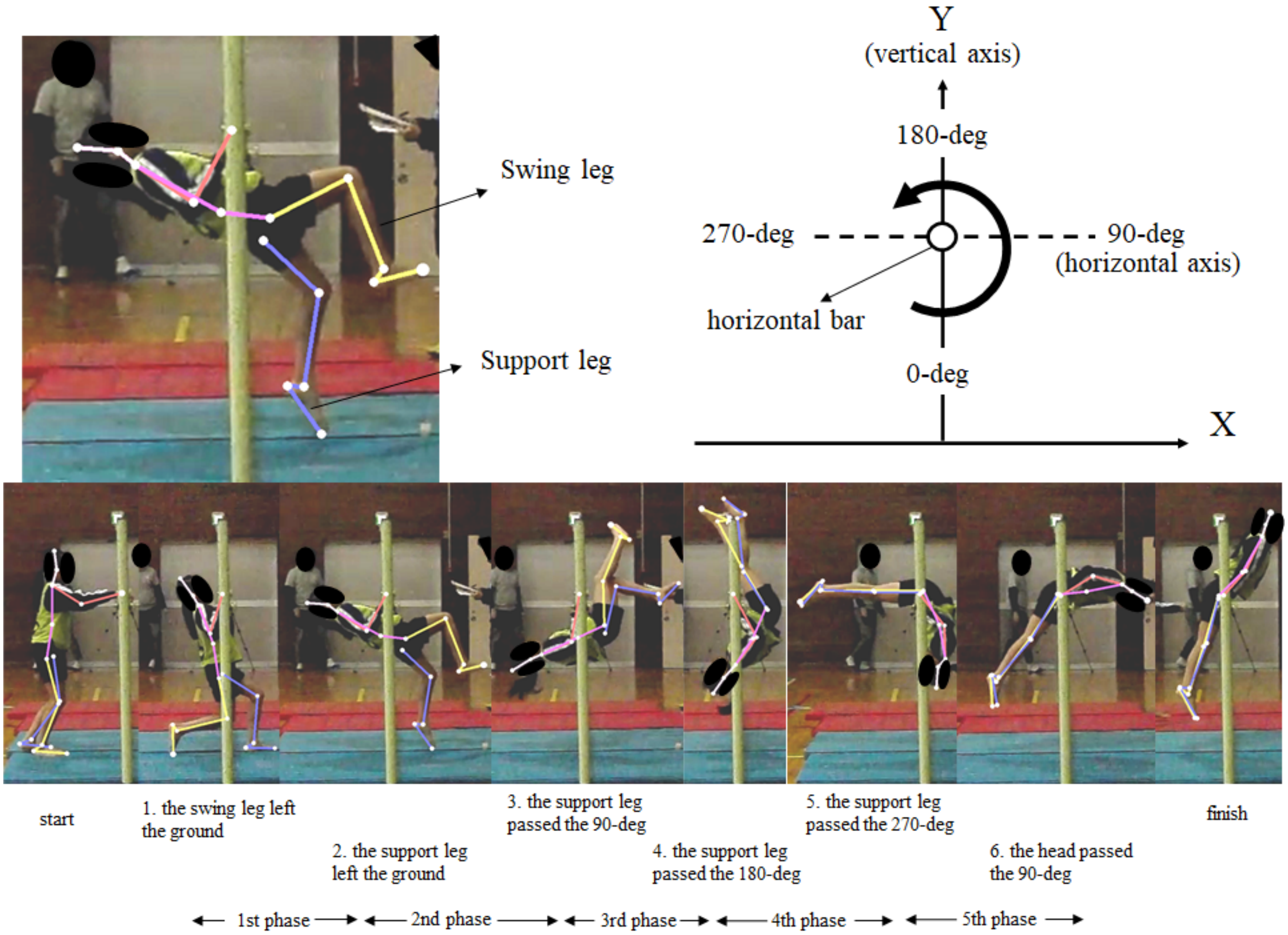

Figure 1. Definition of the events and motion phases.

Figure 1 shows the definition of the events and motion phases. The leg that took off first was defined as the swing leg, and the leg that took off second was defined as the support leg. Moreover, 90-deg (horizontal axis), 180-deg (vertical axis), and 270-deg (horizontal axis) points were defined counterclockwise from the standard point (0-deg, vertical axis), which was perpendicular to the horizontal bar. These events were obtained from the coordinate data or the video images. The following frames were collected: 1. the frame when the foot of the swing leg left the ground, 2. the frame when the foot of the support leg left the ground, 3. the frame when the foot of the support leg passed the 90-deg point, 4. the frame when the foot of the support leg passed the 180-deg point, 5. the frame when the foot of the support leg passed the 270-deg point, and 6. the frame when the head passed the 90-deg point. Based on each event, the 1st phase was defined as frames 1 and 2, the 2nd phase as frames 2 and 3, the 3rd phase as frames 3 and 4, the 4th phase as frames 4 and 5, and the 5th phase as frames 5 and 6. Finally, the motion time of each phase and the percentage of the whole time were calculated and the time-series data were normalized such that frames 1–6 totaled 100%.

Construction of the motion model and analysis data

A 14-segment link model comprising hands, forearms, upper arms, feet, shanks, thighs, head, and trunk was constructed. The body segment inertia parameters (COM coordinate, segment mass and moment of inertia) were calculated using the Kaup Index and the body segment inertia coefficient of Yokoi et al. [10]. The COM coordinates of each body segment were numerically differentiated to obtain those COM velocities. Whole segment angles were calculated in the sagittal plane, and those angular velocities were obtained by time differentiation. The averaged motion models were obtained as normalized coordinate data for each motion phase time and the body height [11,12].

The following biomechanical variables were calculated: a) motion phase time of each phase, b) trajectory of the head and hip joint (changes in the relative coordinates of the head and the hip joint with the horizontal bar as the origin were used to calculate the trajectory), c) angular momenta about the horizontal bar of the whole body, HAT segment as defined by Yoshioka et al. [13], swing leg, and support leg.

$$\boldsymbol{H}_i = \boldsymbol{I}_i\,\boldsymbol{\omega}_i + \boldsymbol{r}_{i\,/\,bar} \times m_i\,\boldsymbol{V}_{i/bar}$$
$$\boldsymbol{H}_{whole\ body} = \boldsymbol{H}_{HAT\ segment} + \boldsymbol{H}_{swing\ leg} + \boldsymbol{H}_{support\ leg}$$

Here, $\boldsymbol{H}_i$ is the angular momentum about the horizontal bar, $\boldsymbol{I}_i$ is the moment of inertia, $\boldsymbol{\omega}_i$ is the angular velocity, $\boldsymbol{r}_{i/bar}$ is the relative coordinate vector from the horizontal bar to segment i, m_i is the mass of segment i, and $\boldsymbol{V}_{i/bar}$ is the relative velocity between the horizontal bar and segment i (that is, COM velocity of each segment). The angular momentum of the whole body is the sum for all segments, that of the HAT segment is the sum for the head, arms, and trunk, and that of the swing and support legs are the sums for the corresponding thigh, shank, and foot segments.

Statistical Analyses

The intraclass correlation coefficient was calculated to confirm the reliability of the subjective evaluation of the three evaluators. The Mann–Whitney U-test was used to analyze the differences between the two skill-level groups. The level of significance was set at <5%.

RESULTS

As already shown in Table1, no significant differences in any of the body composition indices and grip strength were found between the two groups.

Table 2 shows the motion phase time and the percentage of each phase for all phases in both groups. The 4th phase (excellent group, 0.380 ± 0.182 s; good group, 0.558 ± 0.214 s; | z | = 2.29, p = 0.02) and the total time (excellent group, 1.574 ± 0.321 s; good group, 1.759 ± 0.204 s; | z | = 2.44, p = 0.02) were significantly shorter in the excellent group compared with the good group.

Table 2. Motion phase time of kicking pullover.

	Excellent group (n=13)		Good group (n=13)		Mann-Whitney U-test			
	Mean	S.D.	Mean	S.D.	|Z|	p	mark	1-β
1st phase	0.225s (14.5%)	0.051s (3.1%)	0.220s (12.7%)	0.039s (2.9%)	0.00	1.00	n.s.	0.06
2nd phase	0.238s (15.4%)	0.044s (3.4%)	0.237s (13.6%)	0.023s (1.6%)	0.36	0.72	n.s.	0.05
3rd phase	0.242s (15.7%)	0.057s (4.0%)	0.273s (15.6%)	0.083s (4.8%)	0.87	0.38	n.s.	0.18
4th phase	0.380s (23.4%)	0.182s (7.9%)	0.558s (31.3%)	0.214s (9.8%)	2.29*	0.02	p<0.05	0.57
5th phase	0.488s (30.9%)	0.167s (6.9%)	0.471s (26.8%)	0.126s (7.4%)	0.59	0.56	n.s.	0.06
Total time	1.574s (100.0%)	0.321s (0.0%)	1.759s (100.0%)	0.204s (0.0%)	2.44*	0.02	p<0.05	0.38

*Statistically significant, Mann-Whitney U-test.

Figure 2 shows the sticks of the averaged motion model constructed from the kicking pullover attempts as well as the trajectories of the head and the hip joint of both groups. From the average motion models, a difference in the backward lean of the HAT segment (especially the trunk) during the 4th phase (50%–70% time) was observed between the groups.

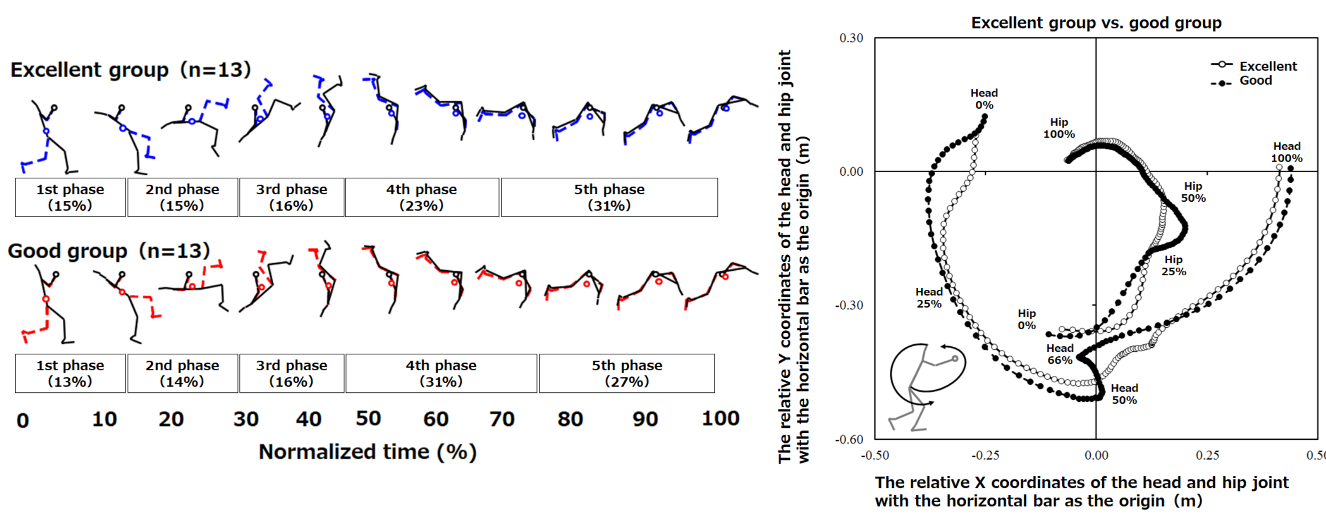

Figure 2. Averaged motion models and trajectories of head and hip joint.

In the excellent group, the trajectory of the head continued rotating counterclockwise during the 4th phase. However, the relative X-coordinate of the head switched from positive values to negative values after 50% time in the good group. The X-coordinate of the head at 66% time showed a significant difference between the two groups (excellent group, 0.11 ± 0.19 m; good group, −0.04 ± 0.17 m; | z | = 2.00, p = 0.04). No significant difference in the X-coordinate of the hip joint from 25% to 50% time was found between the two groups.

Figure 3 shows the changes in the whole body, the HAT segment, the swing leg, and the support leg in terms of angular momentum about the horizontal bar. At the top of the graph, the normalized time when significant differences in the U-test were found between the groups are marked for clarity ($p < 0.05$). The counterclockwise rotation of the angular momentum of the whole body in the excellent group tended to gradually decrease from 0% to 100% time. The angular momentum of the whole body between 55% and 65% time was significantly larger in the excellent group than in the good group. In contrast, the angular momentum of the whole body between 85% and 90% time in the good group was significantly larger than in the excellent group. There was a significant difference in the angular momentum of the HAT segment between 55% and 60% time, with a counterclockwise rotation in the excellent group and a clockwise rotation in the good group. The counterclockwise rotation of the angular momentum in the swing leg between 15% and 20% time was significantly larger in the excellent group than in the good group. The counterclockwise rotation of the angular momentum in the support leg between 10% and 15% time was significantly larger in the good group than in the excellent group. In contrast, angular momentum in the support leg between 30% and 50% time was significantly larger in the excellent group than in the good group.

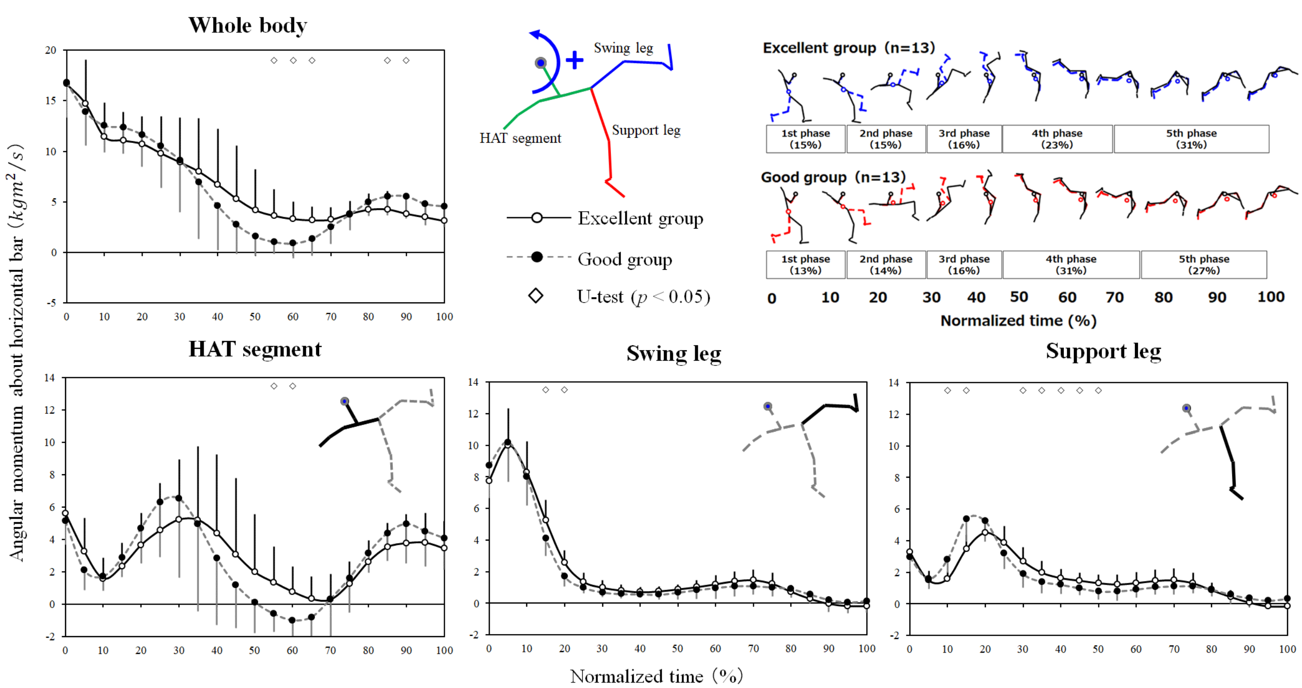

Figure 3. Changes in the angular momentum about the horizontal bar.

DISCUSSION

Technical characteristics of a successful attempt

Some previous studies on the kicking pullover have compared the technical characteristics of successful and unsuccessful attempts [3,4,5] and clarified the techniques of the former [6,7]. However, the current elementary school curriculum guidelines in Japan stipulate that the goal of gymnastics in a physical education class is not only to be able to successfully perform the techniques, but to do so with more artistic and beautiful movements [1]. Therefore, children who have already achieved the kicking pullover technique need to be taught about new technical characteristics so that they can perform more artistic and beautiful movements.

The 26 subjects in this study were classified into an excellent group (12 points or more; n=13) and a good group (11 points or less; n=13,) according to the subjective evaluation of three evaluators. Also, there were no significant differences in body composition indices and grip strength between the two groups (Table 1). These results suggest that physical characteristics do not affect the skill level involved in performing the kicking pullover in elementary school children. In other words, technical characteristics are considered to have a greater effect on the skill level of performing the kicking pullover compared with physical characteristics.

The motion phase time during the 4th phase and the total time of the excellent group were significantly shorter compared with the good group (Table 2). This result suggests that performing the kicking pullover technique in as short a time as possible leads to a good evaluation and an improved skill level. One of the factors in the 4th phase time difference was the angular momentum of the whole body. The counterclockwise rotation of the angular momentum of the whole body during the 4th phase (55%–65% time) was significantly larger in the excellent group than in the good group. Although there was no significant difference in the angular momentum in the swing and support legs, there was a significant difference in the angular momentum of the HAT segment during the 4th phase (55%–60% time), with counterclockwise rotation in the excellent group and clockwise rotation in the good group (Figure 3). Therefore, it is considered that the motion of the trunk during the 4th phase has a great effect on the angular moment of the whole body. Hashizume and Takamura [3] reported that leaning the trunk backward after takeoff has a positive effect on the backward rotation of the whole body. In addition, Takahashi [14] pointed out that even children with weak muscles could successfully perform the kicking pullover technique by leaning the trunk backward. Taken together, these findings suggest that the backward lean of the HAT segment has a large effect on the counterclockwise rotation of the angular momentum of the whole body because of the large inertia it provides.

The trajectory of the head seems to be one of the main technical characteristics for evaluating the movement of the HAT segment. Okamoto and Ichikawa [15] pointed out that moving the head as far from the horizontal bar as possible increased the radius of rotation between the head and the horizontal bar, thereby enabling an increase in the angular momentum of the body. The results of the present study indicate that during the 4th phase, the trajectory of the head in the excellent group tended to rotate farther from the horizontal bar compared with that in the good group (Figure 2). Therefore, it is considered that rotating the head as far from the horizontal bar as possible enables the maintenance of the counterclockwise rotation of angular momentum in the HAT segment and the whole body during the 4th phase. However, although no significant difference was found in the X coordinate of the hip joint from 25% to 50% time between the two groups, the hip joint in the good group tended to pass farther from the horizontal bar compared with the excellent group. These results suggest that the increase in the distance from the horizontal bar to the hip joint before the 4th phase may prevent the backward leaning of the trunk. In summary, this study newly clarified that maintaining the angular momentum of the

HAT segment during the 4th phase is a technical characteristic for improving the skill level from the good group to the excellent group.

The role of each segment in generating and maintaining angular momentum of the whole body

The counterclockwise rotation of the angular momentum of the whole body in the excellent group tended to gradually decrease from 0% to 100% time (Figure 3). The angular momentum of the swing leg, support leg, and HAT segment accounted for most of the angular momentum of the whole body during the 1st, 2nd, and 3rd phases, respectively. In the excellent group, the counterclockwise rotation of the angular momentum of the whole body was generated and maintained by 'a kinetic chain' consisting of the angular momentum of each segment. In contrast, in the good group, the peak of the angular momentum of the HAT segment and support leg tended to appear earlier compared with the excellent group. These results suggest that the kinetic chain in the good group may not contribute well to generating and maintaining the angular momentum of the whole body. In the following, we explain the effective kinetic chain, that is, the role of each segment in generating and maintaining angular momentum of the whole body.

First, we consider the role of the swing leg in generating angular momentum of the whole body. The counterclockwise rotation of the angular momentum of the swing leg during the 1st phase (15%–20% time) was significantly larger in the excellent group than in the good group. Konosu et al. [7] revealed that the swing leg contributes substantially to generating angular momentum of the whole body about the CoM during the contact phase with the ground. In the present study, the motion phase covers not only the contact phase (1st phase) but also the non-contact phase with the ground (2nd-5th phases), and the angular momentum is evaluated about the horizontal bar rather than the CoM. Although the analysis method in this study differs from that of Konosu, our results are in line with theirs. These results suggest that generating angular momentum of the swing leg as much as possible from the contact phase to immediately after takeoff is a very important factor in successfully performing the kicking pullover technique.

Next, we consider the role of the support leg in generating the angular momentum of the whole body during the contact and the non-contact phases. During the 1st phase, the peak of the angular momentum about the horizontal bar of the support leg is smaller than that of the swing leg. Although the ground reaction force could not be measured in this study, Konosu et al. [6] reported that the vertical component of the ground reaction force amounted to approximately 2.6 times the body weight during the contact phase with the ground. Therefore, it is considered that the role of the support leg during the 1st phase is to generate the vertical ground reaction force as much as possible and push up the whole body rather than generate the angular momentum of the body.

After takeoff, the angular momentum of the support leg was significantly larger in the excellent group than in the good group between 30% and 50% time (Figure 3). Shimizu et al. [8] reported that the maximum angular velocity of the support leg during the non-contact phase in the good group appeared earlier than in the excellent group. The counterclockwise rotation of angular momentum in the swing leg decreases after the 1st phase, and thus the support leg needs to provide assistance to maintain the angular momentum of the whole body. These results suggest that delaying the swing timing of the support leg after the takeoff enables maintaining the angular momentum of the whole body until the end phase.

Finally, we consider the role of the HAT segment in maintaining the angular momentum of the whole body during the 5th phase. As mentioned above, the angular momentum of the HAT segment during the 4th phase was an important technical characteristic in separating the good group from the excellent group. The HAT segment also plays a role in increasing the angular momentum of the whole body during the 5th phase because the angular momenta of the swing and support legs were close to zero during the 5th phase. The angular momentum of the whole body between 85% and 90% time was significantly larger in the good group than in the excellent group. In the good group, the counterclockwise rotation of the angular momentum of the whole body was not maintained during the 4th phase, and thus it is considered that it was necessary to complete the rotation by increasing the angular momentum of the HAT segment (that is, by raising the trunk and head) during the 5th phase.

Since the results of this study were obtained from the 2-dimensional analysis by digitizing, some suggestions may not always be applicable for teaching from the frontal plane, which is one of the limitations of this study. We also could not measure detailed muscular force because physical education class time was limited. Therefore, we would like to clarify the new technical skills by obtaining the 3-dimensional motion data, the ground reaction force data of the support leg and the muscular force in the future. However, we newly clarified that teachers need to focus on the body position of the trunk and head during the 4th phase in order for elementary school children to succeed in kicking pullovers more beautifully at a higher level.

Conclusions

This study aimed to clarify the differences in body positions and the role of the swing leg, support leg, and HAT segment in generating and maintaining angular momentum of the whole body about the horizontal bar as well as how to improve the skill level of successful kicking pullover attempts. Successful kicking pullover attempts of 26 fifth-grade elementary school children were classified into excellent and good groups according to the subjective evaluation of three evaluators.

Although there were no significant differences in body composition indices among the two groups, the motion phase time during the 4th phase and the total time were significantly shorter in the excellent group than in the good group. These results suggest that performing the kicking pullover attempt in as short a time as possible leads to an improved skill level.

The counterclockwise rotation of the angular momentum of the whole body in the excellent group tended to gradually decrease from 0% to 100% time. The angular momentum of the swing leg, support leg, and HAT segment accounted for most of the angular momentum of whole body during the 1st, 2nd, and 3rd phases, respectively. The counterclockwise rotation of the angular momentum of the whole body during the 4th phase was significantly larger in the excellent group than in the good group. These results suggest that maintaining the angular momentum of the HAT segment during the 4th phase leads to attempts with a shorter time and improves skill level from the good group to the excellent group. The good group was not able to maintain angular momentum of the whole body during the 4th phase because the peak of the angular momentum of the HAT segment and support leg tended to appear earlier compared with the excellent group. we newly clarified that teachers need to focus on the body position of the trunk and head during the 4th phase in order for elementary school children to succeed in kicking pullovers more beautifully at a higher level.

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REFERENCES

1. Ministry of Education, Culture, Sports, Science and Technology. [Commentary of government educational guidelines of Physical Education for junior high school]. Tokyo: Touyoukan; 2018. p. 125. Japanese.

2. Hayashi S, Hata O, Ikeda N, Maeda K, Koyama S. [A study on the skill of the improvement of "the physical fitness and formation of daily sports behavior and basic skill for elementary school students"]. Bull Jpn Womans Coll Phys Educ. 2009; 39: 35-45. Japanese.

3. Hashizume K, Takamura K. [A study on the coordinated movement of SAKA-AGARI performance by measuring the ground reaction forces]. Jpn J Ped Phys Educ. 2005; 21: 11-20. Japanese.

4. Okuno M, Domoto K. [University student's flexibility of feet first somersault on a horizontal bar: comparison just before the acquisition just after that]. Bull Univ Shitennogi. 2016; 61: 95-107. Japanese.

5. Konosu A, Ikeda N, Yoshioka S, Yanagihara D, Fukashiro S. Biomechanical differences between successful and unsuccessful kicking pullovers by 10-year-old children. Int J Sport Health Sci. 19: 1-9, 2021.

6. Konosu A, Yoshioka S, Fukashiro S. Upper limb joint torques during performances of kicking pullovers. Int J Sport Health Sci. 2017; 15: 137-144.

7. Konosu A, Yoshioka S, Yanagihara D, Fukashiro S. Radial movements and lower limb joint kinematics during the takeoff phase of kicking pullovers. Int J Sport Health Sci. 2020; 18: 39-47.

8. Shimizu Y, Nishimura S, Matsushita S. Technical tasks in forward upward circling performed by elementary school children according to skill level. J Phys Educ Sport. 2020; 20: 1884-1895.

9. Winter DA. Biomechanics and motor control of human movement. 4th edn. Hoboken, NJ: John Wiley and Sons; 2009. pp. 70-73.

10. Yokoi T, Shibukawa K, Ae M. [Body segment parameters of Japanese children]. Jpn J Phys Educ. 1986; 31: 53-66. Japanese.

11. Ae M, Muraki Y, Koyama H. A biomechanical method to establish a standard motion and identify critical motion by motion variability: With examples of high jump and sprint running. Bull Inst Health Sport Sci. Univ. Tsukuba. 2007; 30: 5-12.

12. Shimizu Y, Ae M, Fujii N, Koyama H. Technique types of preparatory and take-off motions for elite male long jumpers. Int. J. Sport Health Sci. 2018; 16: 200-210.

13. Yoshioka S, Nagano A, Hay D C, Fukashiro S. Peak hip and knee joint moments during a sit-to-stand movement are invariant to the change of seat height within the range of low to normal seat height. BioMedical Engineering OnLine. 2014; 13-26.

14. Takahashi T. [New class study of physical education]. Tokyo: Daishukan Bookstore; 1989. pp. 66-88. Japanese.

15Okamoto A, Ichikawa M. [Biomechanics of forward support rotation on a horizontal bar]. Bull. Tokai Gakuen Univ. Educ. Res. 2018; 4: 11-16. Japanese.

TOPICS IN EXERCISE SCIENCE AND KINESIOLOGY

Angular Momentum in Skilled Kicking Pullover Performed by Elementary School Children

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PURPOSE

This study aimed to clarify the differences in body positions and the role of the swing leg, support leg, and head-arm-trunk (HAT) segment in generating and maintaining angular momentum of the whole body about the horizontal bar as well as how to improve the skill level of successful kicking pullover attempts.

MAIN RESULTS

Successful kicking pullover attempts of 26 fifth-grade elementary school children were classified into an excellent group (12 points or more, males = 7, females = 6) and a good group (11 points or less, males = 6, females = 7) according to the subjective evaluation of three evaluators. **Figure 1** shows the changes in the whole body, the HAT segment, the swing leg, and the support leg in terms of angular momentum about the horizontal bar.

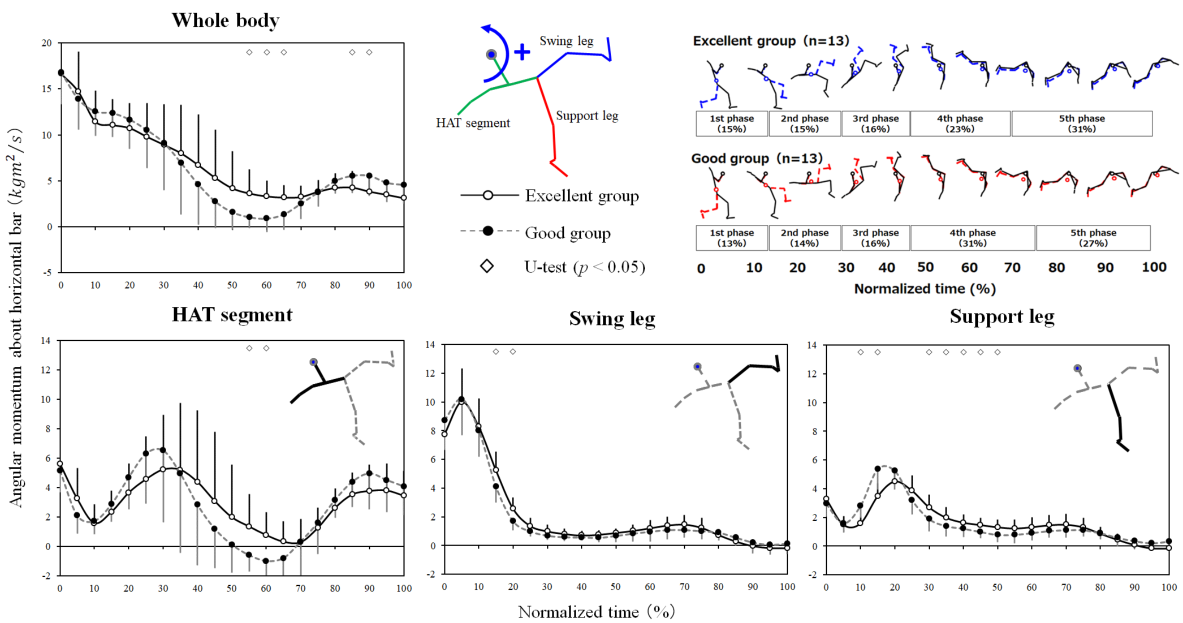

Figure 1. Changes in the angular momentum about the horizontal bar.

- The angular momentum of the whole body between 55% and 65% time was significantly larger in the excellent group than in the good group.
- There was a significant difference in the angular momentum of the HAT segment between 55% and 60% time, with a counterclockwise rotation in the excellent group and a clockwise rotation in the good group.
- These results suggest that maintaining the angular momentum of the HAT segment during the 4th phase leads to attempts with a shorter time and improves skill level from the good group to the excellent group.