EXAMINATION OF MOVEMENT PATTERNS THAT REFLECT THE PROFICIENCY LEVEL IN STRADDLE VAULT FOR ELEMENTARY SCHOOL CHILDREN

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Abstract
The purpose of the present study was to examine movement patterns that reflect the proficiency of straddle vault in elementary school students and to clarify the differences in the movement of technique depending on gender, grade, and height of the vaulting box. The subjects were 453 children (220 boys, 233 girls) from the 3rd-6th grade. Their straddle vault movements were recorded from the left and front sides and scored by the observational evaluation criterion. Latent class analysis was used to extract the movement patterns of straddle vault. The probability of belonging to each movement pattern was tabulated by gender, grade, and height of the vaulting box. To investigate the characteristics of the movements for gender, grade, and height of the box, we performed a $\chi 2$ *test and residual analysis. As a result of identifying the movement patterns by latent class analysis, it became clear that the straddle vault movements of elementary school children can be categorized into five groups: Failure vaulting, Arm dependent vaulting, Unstable landing vaulting, Stable vaulting, and Strong push-off vaulting. There was no difference between boys and girls in the appearance rate of the movement patterns (*$\chi 2=7.707$, $p>0.05$*). Although there was a significant difference in the appearance rate of patterns between grades (*$\chi 2=42.615$, $p<0.01$*), but highly proficient movements didn't tend to increase as the grades increased. The five movement patterns clarified in this study are thought to lead to the detailed evaluation of children's straddle vault movements and the enhancement of instruction according to their proficiency.*

Keywords: *physical education, proficiency, vault, elementary school, latent class analysis.*

INTRODUCTION

Gymnastics enhances muscular and functional fitness, cultivates the movement exhibition of the learner (Hedbávný et al., 2017), and develops their physical self-concept (Rudd et al., 2017). In school education, gymnastics, including frequent changes in body position and movements in different directions, is considered to be the key type of movements in children's motor development (Pajek et al., 2010). Even in Japan, gymnastics is positioned as one of the areas of exercise that make up physical education (PE), and in the course of study, gymnastics is said to be an exercise that allows children to enjoy acquiring skills by engaging in various movements and challenging basic and advanced techniques that suit their abilities (Ministry of education, 2017). Gymnastics in PE of the elementary school consists of three contents: mat exercise, horizontal bar exercise, and vaulting box exercise.

Looking at the vaulting box exercise, the most rudimentary and basic technique is straddle vault (Kaneko, 1987). In other words, straddle vault has the same technical tasks as the advanced techniques learned in PE (e.g. squat vault), and it is desirable to acquire it at the elementary school stage.

One of the characteristics of gymnastics is that children who can perform the technique and children who cannot do it are separated. For straddle vault, the success or failure of jumping over the box is greatly different. Thus, the technical factors necessary for jumping over the box have been examined by comparing the success and the failure groups (Hisamoto et al., 1986; Hanai, and Maeno, 2014), and in many cases, the instruction focused only on jumping over the box. On the other hand, in gymnastics, it is important to give guidance and tasks by evaluating in detail the proficiency level of the technique (Hosogoe et al., 2001; Pehkonen, 2010), including the viewpoint of not only success or failure but the performance of the movement itself. Regarding fundamental movements (e.g. running, jumping, and throwing) mainly for infants and elementary school children, the movement patterns and evaluation criteria according to motor development have been clarified (Takamoto et al., 2003; Nakamura et al., 2011). However, for the movement technique in the vaulting box exercise, the movement patterns and evaluation viewpoints according to the proficiency level are not obvious. By clarifying the image of the proficiency level of movement and evaluation criteria for straddle vault that are learned in many elementary schools, it is considered that individually optimized instruction based on the proficiency level will be enhanced and the quality of vaulting box exercise class will improve.

In research on exercise movement and motor development, gender and grade or age differences are often examined (Kevin et al., 2013; Shinohara et al., 2016). However, no studies have explained the gender or grade differences in the movement of straddle vault. Besides, it is possible in gymnastics that performing the movement may differ depending on the setting of the instrument. In the vaulting box exercise, the height of the box can make a major difference in the setting of the equipment, but the differences in movement depending on the height of the vaulting box have not been sufficiently examined. Understanding the features of movements caused by differences in gender, grade, and equipment settings will lead to step-by-step instruction and appropriate environment setting to suit individual skills.

The purpose of this study is to identify movement patterns that indicate the proficiency level of straddle vault in elementary school children and to identify the differences in the movement technique in dependence of gender, grade, and height of the vaulting box.

METHODS

Straddle vault is listed as a learning content in the 3rd to 6th grade (3rd: 8-9-year-old, 4th: 9-10-year-old, 5th: 10-11-years-old, 6th: 11-12-year-old) in the Japanese physical education curriculum guidelines (Ministry of Education, 2017). Therefore, the subjects of this study were 453 children from 3rd to 6th grade (220 boys, 233 girls) in three elementary schools in Hyogo prefecture, Japan. These three schools were selected from the general public elementary schools that do not have special physical education programs, taking into consideration the number of children. The survey period was from September 2016 to November 2017, when the vaulting box exercise class was held in the target schools. Prior to the survey, the research content was explained to the principal of the target school and the person in charge of the class. Documents and consent forms regarding the purpose, method, safety and ethics of the research were also distributed to the parents of the children, and consent forms were obtained. The research was approved by the local Research Ethics Committee (No: 211).

In the trial, after warming up and the practice trial of straddle vault twice, the actual trial was videotaped. A video camera was installed in front of and 7.5m to the left of the vaulting box, and fixed shooting was performed at 60 frames per second and a shutter speed of 1/500 second. The vaulting box was a small vaulting box (length: 80cm, height: 60cm (4-box), 70cm (5-box), 80cm (6-box) standardized by the Ministry of Education. The orientation of the vaulting box was set to be vertical, and the height of the vaulting box was decided to be selected from the 4-box to 6-box by children themselves.

Qualitative evaluation by observing movements has come to be widely used in physical education research (Čepička, 2003; Kovač, 2012; Majerič et al., 2016). In this study, the movements of straddle vault performed by elementary school children were evaluated using an observational evaluation criterion. Vaulting in artistic gymnastics is often divided into seven distinctive phases; running, jumping on take-off board, take-off board support, first flight phase, table support, second flight phase, and landing (Čuk and Karacsony, 2004; Atiković and Smajlović, 2009; Atiković, 2012). And, Kovač and Čuk (2003) present a description of the straddle vault technique in seven motion phases: run-up; hurdle step onto the springboard; take-off from the springboard; first flight phase; approach and push-off from the vaulting buck; second flight phase, and landing. In this study, referring to these previous studies, we decided to set six phases that integrate the running and the jumping on the springboard: [1] run-up and hurdle step onto the springboard; [2] take-off from the springboard; [3] first flight phase; [4] approach and push-off from the vaulting box; [5] second flight phase; and [6] landing. The captured video was played back in normal, slow, and frame-by-frame format for evaluation. In consideration of individual differences in approach distance and speed, the range of skills to be evaluated was from 3 steps before the take-off to landing. Table 1 and Table 2 show the observational evaluation criteria for straddle vault. When the children stopped on the vaulting box, the scores of the movements after the second fright phase were set to 0 (not appear). The evaluation was carried out by two graduate students who are engaged with a laboratory specializing in physical education and have experience in observational evaluation of running, jumping, and throwing movements of elementary school children.

To extract movement patterns of straddle vault, we categorized the movement of elementary school children by latent class analysis. The latent class analysis assumes multiple subgroups behind the subject group and extracts different response patterns to categorical observed variables as latent classes. It is possible to estimate the composition ratio of each class and the conditional-response probability to each category of the observed variables. We interpreted the movement patterns from the conditional-response probabilities to each evaluation item and the motion factors that characterize the pattern. Masyn (2013) cites that the conditional-response probability to a certain category is close to 1.0 (0.7 or more) as a condition of the items that characterize the extracted class.

In latent class analysis, increasing the number of estimated parameters may make the model indistinguishable (Miwa, 2009). Therefore, evaluation items that are effective for analysis were selected by the following steps A)- C).

A) We specified a 2-class model with all 30 items and confirmed that failure type and success type of jumping over the box were extracted as the patterns with the clearest difference.
B) Regarding the failure type, items with

the conditional-response probability of 0.7 or more to the highest evaluation category were excluded as items that were easy to achieve even in low-proficiency movements.

C) For the success type, items with the conditional-response probability of 0.7 or more to the lowest evaluation category were excluded as items that were particularly difficult to achieve.

Using the selected items, model estimation was performed while increasing the number of classes by 1, and the optimum number of classes was determined based on the information criteria (Akaike Information Criterion: AIC, Bayesian information criterion: BIC) and likelihood ratio chi-squared statistics (G^2). The movement patterns were interpreted from the conditional-response probabilities of the evaluation items. The poLCA package (Linzer and Lewis, 2011) of statistical software R version 3.6.1 was used for latent class analysis. Considering the problem of the local solution, the estimated number of repetitions with different initial values was specified as 100 times.

The probabilities of belonging to each movement pattern (the class membership probabilities) were tabulated by gender, grade, and height of the vaulting box. The latent class analysis has a feature of soft clustering, and does not uniquely determine the class to which the subjects belong but shows the class membership probabilities, ie., the probabilities that an individual belongs to each class. Therefore, in this study, the number of children in each movement patterns were weighted on the basis of class membership probabilities at the time of aggregation. For example, if the class membership probabilities of student A is 0.7 for class A, 0.2 for class B, and 0.1 for class C, 0.7 in total will be added to class A, 0.2 to class B, and 0.1 to class C. By doing so, the appearance rate of the movement pattern can be examined in more detail based on the estimation result, as compared with the case where the subject belongs to one class. After totaling, to investigate the characteristics of the movements for each gender, grade, and height of the vaulting box, we performed a χ^2 test and residual analysis. The significance level was 0.05, and Cramer's V was used as the effect size of the χ^2 test.

RESULTS

Item selection for Latent class analysis

When a 2-class model was specified using all 30 items, two patterns were extracted: failure type that rides on the vaulting box, and success type that succeeded in jumping over the box. In the failure type, the conditional-response probabilities to the highest evaluation category exceeded 0.7 for 4 items: Item1 (Stride adjustment), Item2 (Speed adjustment), Item4 (Pushing by stepping leg) and Item18 (Aligning both hands). In the success type, the conditional-response probabilities to the lowest evaluation category exceeded 0.7 for 3 items: Item7 (Swing the arm backward), Item10 (Attracting arms) and Item12 (Swing up arms). These 7 items were excluded, and 23 items were used for the latent class analysis.

Table 3 shows the information criteria and likelihood ratio chi-squared statistics when estimating up to 6 class models. The BIC showed the minimum value when the 5-class model was estimated. Therefore, we decided to use a 5-class model in this study.

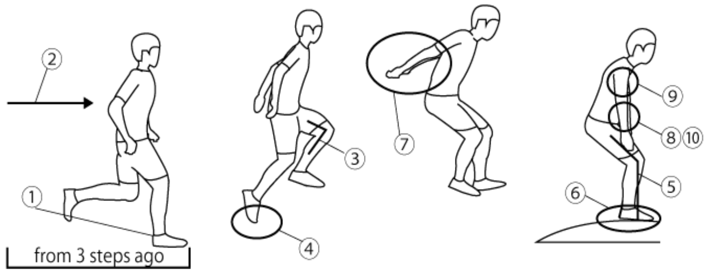
Identification of straddle vault movement patterns by latent class analysis

Table 4, Table 5, and Table 6 show the conditional-response probabilities of the 5-class model. As a result of interpreting the movement patterns based on the probabilities, movement patterns and their composition ratios were *Failure vaulting* (FV) (0.12), *Arm dependent vaulting* (ADV) (0.27), *Unstable landing vaulting* (ULV) (0.31), *Stable vaulting* (SV) (0.24) and *Strong push-off vaulting* (SPV) (0.06).

Table 1

Observational evaluation criterion for straddle vault movement of phase [1]-[3].

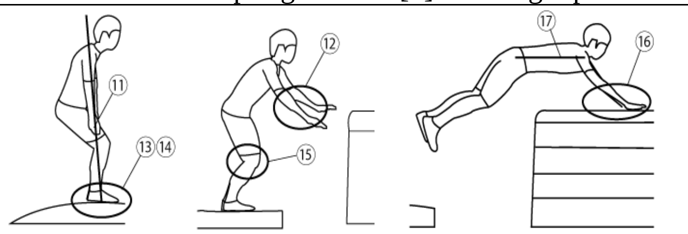
[1] Run-up and hurdle step onto the springboard



1 Stride adjustment
2 Speed adjustment
3 Leading by free leg
4 Pushing by stepping leg
5 Adjusting free leg flexion
6 Aligning legs
7 Swing arms backward
8 Aligning arms
9 Tightening aside
10 Attracting arms

Item		Category/Score 3	2	1
[1]	1	-	Smooth stride	Stride becomes smaller
	2	-	Smooth speed	Speed slows down
	3	-	Knee angle ≦ 90°	Knee angle ＞ 90°
	4	-	There is a flight period	There is no flight period
	5	-	Center of foot below the knee	Heels below the knee
	6	-	Aligned	Not aligned
	7	Stretch and pull arms	Bend and pull arms	Not pull arms
	8	-	Aligned	Not aligned
	9	-	Sides are tight	Sides are open
	10	-	Hands are below the waist	Hands are above the waist

[2] Take-off from the springboard & [3] First flight phase



11 Making a body axis
12 Swing up arms
13 Preemption of grounding
14 Timing of grounding
15 Rebound jump

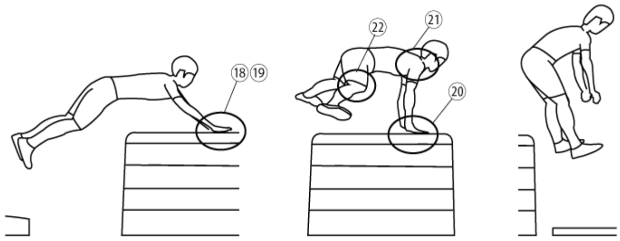
16 Aligning legs
17 Swing arms backward

Item		Category/Score 3	2	1
[2]	11	-	Shoulders, knees, feet are in a straight line	Not in a straight line
	12	Swing up big	Swing up small	Not swing up or swing down
	13	Step on forefoot	Put weight on forefoot	Ground sequentially from heel
	14	-	Ground at the same time	Not ground at the same time
	15	Knees extend at the same time as ground	Knee flexion fixed	Knees flex after ground
[3]	16	Touch box after leg extension	Touch box at the same time as legs extension	Touch box before leg extension
	17	Above shoulder	Above midpoint of shoulders and elbows	Below midpoint of shoulders and elbows

Table 2

Observational evaluation criterion for straddle vault movement of phase [4]-[6].

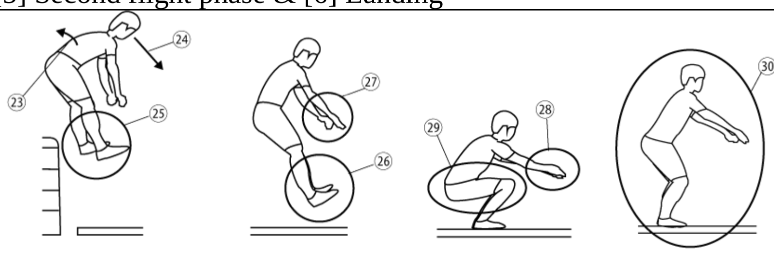
[4] Approach and push-off from the vaulting box



18 Aligning both hands
19 Timing of putting hands
20 Push-off
21 Raising shoulders
22 Keeping legs extended

Item		Category/Score 3	2	1
[4]	18	-	Aligned	Not aligned
	19	-	Touch at the same time	Not touch at the same time
	20	Push-off	Push backwards	Stop or buffer by hand
	21	Shoulders go up	Shoulders move forward	Shoulders stop at the position of hands
	22	-	Open legs with legs extended	Open legs with knees bent

[5] Second flight phase & [6] Landing



23 Rotating backward
24 Looking to the landing position
25 Control of leg swing
26 Closing legs
27 Raising arms

28 Swing down arms
29 Flexing lower limbs
30 Stopping firmly

Item		Category/Score 3	2	1	0
[5]	23	-	Turn back the rotation	Not turn back the rotation	Not appear
	24	-	Look at the landing position	Looking straight down	Not appear
	25	-	Control the swing	Swing legs forward	Not appear
	26	-	Legs are closed and aligned	Not closed and aligned	Not appear
	27	Raise forward	On the side of body	Behind the body	Not appear
[6]	28	Swing arms down	Raise arms	Not swing down or raise	Not appear
	29	Flex hips and knees	Flex knees	Stretch knees	Not appear
	30	-	Stop firmly	Not stop firmly	Not appear

Table 3
Criteria to assess model for latent class analysis.

Number of class	AIC	BIC	G^2	DF	P-value
2	13267.28	13600.66	7576.42	372	p<0.001
3	12711.75	13213.89	6938.89	331	p<0.001
4	12400.22	13071.11	6545.36	290	p<0.001
5	12214.81	13054.45	6277.95	249	p<0.001
6	12159.35	13167.75	6140.49	208	p<0.001

AIC: Akaike Information Criterion
BIC: Bayesian Information Criterion
G^2: Likelihood ratio chi-square statistics
DF: Degree of Freedom

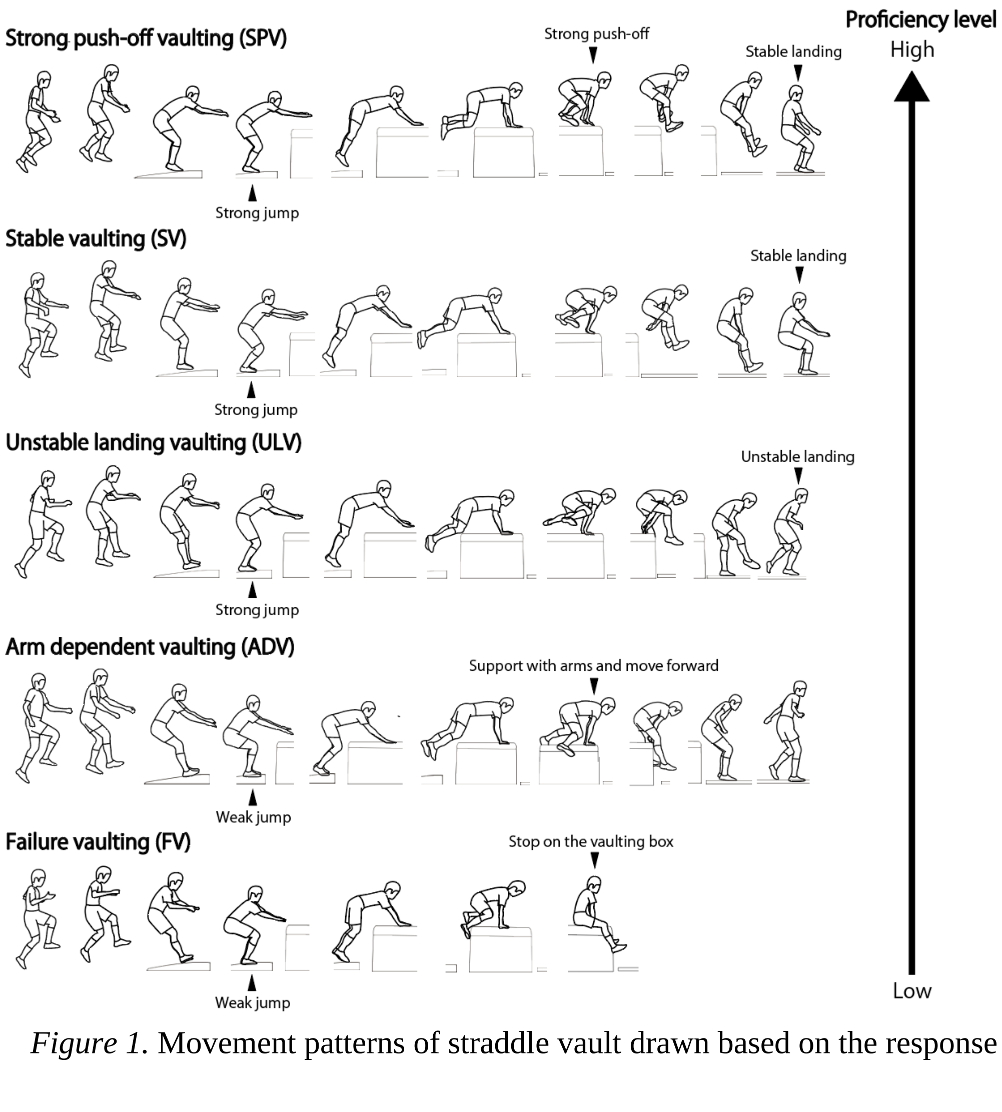


Figure 1. Movement patterns of straddle vault drawn based on the response probabilities.

Table 4
Conditional-response probabilities for latent class analysis of phase [1]-[3].

Item	Category/Score	Failure vaulting	Arm dependent vaulting	Unstable landing vaulting	Stable vaulting	Strong push-off vaulting
[1] Run-up and hurdle step onto the springboard						
3 Leading by free leg						
	2 Knee angle ≦ 90°	0.44	0.53	0.69	0.70	0.73
	1 Knee angle > 90°	0.56	0.47	0.31	0.30	0.27
5 Adjusting free leg flexion						
	2 Center of foot below knee	0.20	0.09	0.88	0.93	0.66
	1 Heels below knee	0.80	0.91	0.12	0.07	0.34
6 Aligning legs						
	2 Aligned	0.57	0.60	0.68	0.74	0.78
	1 Not aligned	0.43	0.40	0.32	0.26	0.22
8 Aligning arms						
	2 Aligned	0.46	0.70	0.64	0.68	0.70
	1 Not aligned	0.54	0.30	0.36	0.32	0.30
9 Tightening aside						
	2 Sides are tight	0.41	0.42	0.56	0.49	0.69
	1 Sides are open	0.59	0.58	0.44	0.51	0.31
[2] Take-off from the springboard						
11 Making a body axis						
	2 Shoulders, knees, feet are in a straight line	0.20	0.30	0.80	0.86	0.87
	1 Not in a straight line	0.80	0.70	0.20	0.14	0.13
13 Preemption of grounding						
	3 Step on forefoot	0.00	0.00	0.11	0.17	0.15
	2 Put weight on forefoot	0.20	0.13	0.85	0.76	0.63
	1 Ground sequentially from heel	0.80	0.87	0.03	0.06	0.22
14 Timing of grounding						
	2 Ground at the same time	0.48	0.54	0.78	0.85	0.81
	1 Not ground at the same time	0.52	0.46	0.22	0.15	0.19
15 Rebound jump						
	3 Knees extend at the same time as ground	0.00	0.00	0.15	0.31	0.26
	2 Knee flexion fixed	0.13	0.11	0.79	0.65	0.58
	1 Knees flex after ground	0.87	0.89	0.05	0.04	0.16
[3] First flight phase						
16 Swing arms forward						
	3 Touch box after leg extension	0.09	0.09	0.20	0.37	0.34
	2 Touch box at the same time as legs extension	0.15	0.39	0.48	0.40	0.44
	1 Touch box before leg extension	0.76	0.52	0.32	0.23	0.22
17 Raising hips						
	3 Above shoulder	0.00	0.04	0.03	0.05	0.11
	2 Above midpoint of shoulders and elbows	0.06	0.61	0.74	0.67	0.77
	1 Below midpoint of shoulders and elbows	0.94	0.34	0.23	0.29	0.12

Table 5
Conditional-response probabilities for latent class analysis of phase [4]-[5].

Item	Category/Score	Failure vaulting	Arm dependent vaulting	Unstable landing vaulting	Stable vaulting	Strong push-off vaulting
[4] Approach and push-off from the vaulting box						
19 Timing of putting hands						
	2 Touch at the same time	0.67	0.75	0.71	0.82	0.89
	1 Not touch at the same time	0.33	0.25	0.29	0.18	0.11
20 Push-off						
	3 Push-off	0.00	0.04	0.02	0.01	0.82
	2 Push backwards	0.00	0.95	0.98	0.99	0.18
	1 Stop or buffer by hand	1.00	0.01	0.00	0.00	0.00
21 Raising shoulders						
	3 Shoulders go up	0.00	0.11	0.04	0.16	0.96
	2 Shoulders move forward	0.00	0.88	0.96	0.84	0.04
	1 Shoulders stop at the position of hands	1.00	0.01	0.00	0.00	0.00
22 Keeping legs extended						
	2 Open legs with legs extended	0.41	0.80	0.73	0.86	0.93
	1 Open legs with knees bent	0.59	0.20	0.27	0.14	0.07
[5] Second flight phase						
23 Rotating backward						
	2 Turn back the rotation	0.00	0.00	0.00	0.00	0.67
	1 Not turn back the rotation	0.00	1.00	1.00	1.00	0.33
	0 Not appear	1.00	0.00	0.00	0.00	0.00
24 Looking to the landing position						
	2 Look at the landing position	0.00	0.65	0.40	0.67	0.93
	1 Looking straight down	0.00	0.35	0.60	0.33	0.07
	0 Not appear	1.00	0.00	0.00	0.00	0.00
25 Control of leg swing						
	2 Control the swing	0.00	0.07	0.02	0.00	0.67
	1 Swing legs forward	0.54	0.93	0.98	1.00	0.33
	0 Not appear	0.46	0.00	0.00	0.00	0.00
26 Closing legs						
	2 Legs are closed and aligned	0.00	0.57	0.40	0.91	0.93
	1 Legs are not closed and aligned	0.00	0.43	0.60	0.09	0.07
	0 Not appear	1.00	0.00	0.00	0.00	0.00
27 Raising arms						
	3 Raise forward	0.00	0.03	0.00	0.00	0.28
	2 On the side of the body	0.00	0.16	0.14	0.24	0.68
	1 Behind the body	0.00	0.81	0.86	0.76	0.04
	0 Not appear	1.00	0.00	0.00	0.00	0.00

Table 6
Conditional-response probabilities for latent class analysis of phase [6].

Item	Category/Score	Failure vaulting	Arm dependent vaulting	Unstable landing vaulting	Stable vaulting	Strong push-off vaulting
[6] Landing						
28 Swing down the arms						
	3 Swing arms down	0.00	0.03	0.00	0.12	0.14
	2 Raise arms	0.00	0.39	0.25	0.44	0.45
	1 Not swing down or raise	0.00	0.57	0.75	0.44	0.41
	0 Not appear	1.00	0.00	0.00	0.00	0.00
29 Flexing the lower limbs						
	3 Flex hips and knees	0.00	0.11	0.01	0.40	0.07
	2 Flex knees	0.00	0.60	0.39	0.60	0.78
	1 Stretch knees	0.00	0.28	0.59	0.00	0.15
	0 Not appear	1.00	0.00	0.00	0.00	0.00
30 Stopping firmly						
	2 Stop firmly	0.00	0.34	0.00	0.84	0.67
	1 Not stop firmly	0.00	0.66	1.00	0.16	0.33
	0 Not appear	1.00	0.00	0.00	0.00	0.00

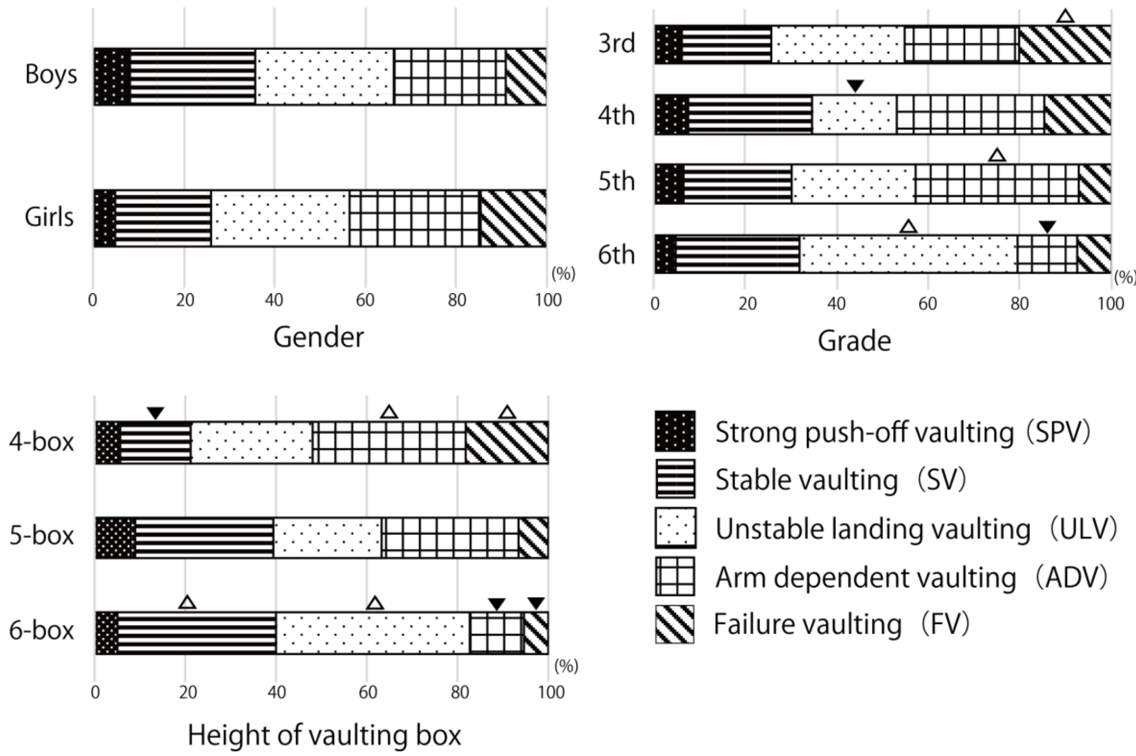


Figure 2. Appearance rates of straddle vaulting patterns by gender, grade, height of vaulting box. The white triangles indicate that the appearance rate is significantly higher than in the other groups. The black triangles indicate that the incidence is significantly lower than in the other groups. The significance level was 0.05.

FV showed a movement to stop on the vaulting box because the response probabilities to score 0 were 1.00 for the evaluation items after the second flight phase: from Item23 to Item30. Since the response probabilities to score 1 were 1.00 for the two items: Item20 (Push-off) and Item21 (Raising shoulders), FV cannot move the weight forward with arm support. Also, the response probabilities to score 1 were high in Item13 (Preemption of grounding: 0.80), Item15 (Rebound jump: 0.87), and Item17 (Raising hips: 0.94). Therefore, in FV, the movement was such that the heel touched the springboard, the knees bend deeply in take-off, and the hips were not sufficiently raised.

In ADV, the response probabilities to score 2 were high in Item20 (Push-off: 0.95) and Item21 (Raising shoulders: 0.88). Therefore, weight transfer by arm support was achieved, and jumping over the box was successful. However, as with FV, the response probabilities to score 1 were high in Item13 (Preemption of grounding: 0.87), Item15 (Rebound jump: 0.89), so the bouncy take-off movement was still not achieved. In ULV, weight transfer by arm support was achieved as in ADV. Since the response probabilities to score 2 were high in Item13 (Preemption of grounding: 0.85), Item15 (Rebound jump: 0.79), a bouncy take-off movement was achieved. On the other hand, the response probabilities of score 1 evaluation were high in Item28 (Swing down the arms: 0.75), Item29 (Flexing the lower limbs: 0.59), and Item30 (Stopping firmly: 1.00) in the landing phase, so the landing was unstable.

SV achieved bouncy jumping and weight transfer. Furthermore, the response probabilities to score 2 were high in Item29 (Flexing the lower limbs: 0.59) and Item30 (Stopping firmly: 0.84), so the desired landing posture was achieved. In SPV, the probabilities to the highest evaluation of score 3 were high in Item20 (Push-off: 0.82) and Item21 (Raising shoulders: 0.96). From this, unlike other patterns, stronger hand push-off was accompanied.

Figure 1 shows an illustration of each movement pattern based on the response probabilities of 23 evaluation items.

Appearance rate of movement patterns by gender, grade, and height of the vaulting box

Figure 2 shows the appearance rates of straddle vaulting patterns by gender, grade, and height of the vaulting box. As a result of the $\chi 2$ test, no significant difference was found in the appearance rate of movement patterns depending on gender ($\chi 2 = 7.707$, $p > 0.05$, Cramer's V = 0.130).

Regarding the appearance rate by grade, a significant difference was found in the appearance rate of the movement patterns ($\chi 2 = 42.615$, $p < 0.01$, Cramer's V = 0.177). As a result of residual analysis, the appearance rate was significantly higher for FV in the 3rd grade and significantly lower for ULV in the 4th grade. In the 5th grade, ADV was significantly higher. In the 6th grade, ULV was significantly higher and ADV was significantly lower.

A significant difference was found in the appearance rate of the movement patterns depending on the height of the vaulting box ($\chi 2 = 54.144$, $p < 0.01$, Cramer's V = 0.364). As a result of the residual analysis, SV and ULV were significantly higher, ADV and FV were significantly lower in the 6-box set. ADV and FV were significantly higher, and SV was significantly lower in the 4-box set.

DISCUSSION

Item selection and movement patterns of straddle vault

As a result of estimating the number of classes based on the BIC, the 5-class model was judged the most suitable. From this, it is not sufficient to evaluate the proficiency level of straddle vault movement of children based only on the success or failure of jumping over the box. It is also shown that it is easier to explain by considering that some qualitatively different movement patterns are latent among the movements that support jumping over the box.

The movement patterns of straddle vault derived by the latent class analysis were *failure vaulting*, *arm dependent vaulting*, *unstable landing vaulting*, *stable vaulting*, and *strong push-off vaulting*. The five movement patterns were classified by the degree of achievement of the take-off skill, the support and push-off skill, and the landing skill, which Kaneko (1987) cites as the basic skills of the vaulting box movement. Weight transfer by arm support, which is seen in ADV, is said to be a movement seen in the early stage of learning to straddle vault when the take-off is not yet strong (Yamashita, 1996). Therefore, ADV was considered to be a valid next proficiency stage for FV. ULV achieves a one-legged take-off from the run-up and a bouncy jumping on the springboard. Hedbávný and Kalichová (2015) reported that one of the common characteristics of high-performing gymnasts in the vault is an acceleration in the phase of leaving the springboard and it leads to optimal preparation for the first flight phase. At the stage of ADV, the knees are bent deeply at the take-off and the momentum is stopped, while at ULV, it accelerates smoothly and enteres the first flight phase vigorously. It is thought that this difference in movement can be evaluated from the two movement patterns. If the momentum at the take-off can be secured, the next problem is landing. Mills (2005) stated that there is a trade-off between the difficulty of the technique and the stable landing, and the higher the difficulty of the technique, the more difficult it is to land. It is thought that the point of distinguishing ULV and SV is whether or not the magnificent performance that makes use of the momentum of the take-off is well balanced with the stability of landing. To achieve SPV, it is essential to push the vaulting box strongly with both hands. In the vault, Gervais (1994) cited the variables of height and distance of the second flight phase as factors to minimize the deduction of the technique. Koha and Jennings (2007) also stated an increase in the vertical horse take-off velocity of the center of mass at the end of impact as one of the important factors for maintaining a perfect body layout position in the second flight phase. The push-off motion is exactly what allows jumping upwards from the vaulting box, so SPV is considered to be extracted as a movement pattern that includes the most important and most proficient skills. In this way, the five straddle vault movement patterns derived by the latent class analysis not only show the quality of the statistical index (BIC), but also it reflects the achievement of movements important to the vaulting technique pointed out in previous studies at each stage. Therefore, it seems that the five movement patterns have content validity.

The composition ratio of FV was 0.12, so 1 in 10 children could not jump over the vaulting box. The ratios of ADV, ULV, and SV ranged from 0.2 to 0.3. These three patterns are distinguished by the degree of achievement of the take-off, the push-off, and the landing, which are the basic skills of the vaulting box exercise. Therefore, it is important to select a practice method and provide feedback according to each movement pattern. On the other hand, SPV that allowed the vaulting box to be strongly pushed out by hand to sharply turn back the rotation had a low composition ratio of 0.06. From this, it can be deduced that most children did not learn the strong push-off movement at the elementary school stage. However, it is important to gradually acquire a sense of the strong push-off movement because it is necessary for learning advanced techniques after junior high school.

Appearance rate of movement patterns by gender, grade, and height of the vaulting box

There was no significant difference in the appearance rate of movement patterns by gender. Kato et al. (2014) reported that there was no gender difference between the forward and backward roll movements of the mat exercise, which is the learning content of gymnastics as well as the vaulting box exercise. It is suggested that the technique of gymnastics involves extraordinary movements, and there are few elements of exerting muscular strength and power exertion. Therefore, even in the straddle vault, gender did not significantly affect the proficiency level of the movement.

The appearance rate of FV was higher than 20% in the 3rd grade and less than 10% in the 5th and 6th grades. From this, the achievement rate improves as the grade progresses from the viewpoint of success or failure of jumping over the box. On the other hand, the appearance rates of the highly proficient SV and SPV were slightly higher in the 4th grade, so it cannot be said that highly proficient movements increase with the grade. Kokudo (2017) reported that there may be a phenomenon called "adolescent awkwardness" in which physical balance is lost due to rapid development and motor movements become awkward during puberty. Especially in boys, the 5-6th grade approach the rapid growth period, so it is also possible that the imbalance of the body leads to a disturbance of the aerial posture and landing, which is likely to be a factor in the increase of ULV.

About the height of the vaulting box, the appearance rates of ULV and SV, which were movement patterns with a bouncy take-off, were high at the 6-box set. Jumping too strong leads to an unstable landing in ULV. Many injuries during gymnastics have been reported to occur on landing (Paschalis et al., 2015). Considering safety, when trying to challenge a high vaulting box, it is necessary to sufficiently improve the skill for stable landing. On the other hand, there are many FV in the 4-box vaulting box, so children with low skill levels often selected 4-box in the survey. However, since there were also many ADV at the 4-box set, to develop the movement with a strong take-off, it is effective to encourage the challenge of a higher vaulting box while considering the physique of the children.

Limitations and future research

In this study, we evaluated the straddle vault movements for children enrolled in three elementary schools in Hyogo prefecture, selected the optimum number of classes based on the information criterion, and identified the movement patterns. However, when the number of samples is increased or other groups are targeted, the number of extracted classes and movement patterns may differ. Therefore, in the future, it will be necessary to conduct additional tests for children.

It has been pointed out that physique and body composition affect the performance of exercise (Laura et al, 2018), which also applies to vaulting box exercise. The children themselves chose the height of the vaulting box in this study. Therefore, they may have selected a height that does not suit their physique. Since the incompatibility between their physique and the height of the vaulting box may be related to the appearance of movement patterns, it will be necessary to examine the relationship between the student's physique and the movement of the technique.

CONCLUSION

The purpose of the present study was to examine movement patterns that reflect the proficiency of straddle vault movements in elementary school children. As a result of identifying the movement patterns by latent class analysis, straddle vault movements of elementary school children can be categorized into five: *failure vaulting*, *arm dependent vaulting*, *unstable landing vaulting*, *stable vaulting* and *strong push-off vaulting*. The movement patterns extracted by the latent class analysis in this study correspond to the findings of previous studies on techniques and are considered to be useful for evaluating the proficiency level.

There is no difference between boys and girls in the appearance rate of the movement patterns. As the grades increase, the incidence of *failure vaulting* decreases, but there is no consistent tendency for the appearance of highly proficient movements (*stable vaulting* and *strong push-off vaulting*) to increase. It is also clarified that when the height of the vaulting box is 6-box, the appearance rate of the movement patterns with a strong take-off is high (*unstable landing vaulting* and *stable vaulting*).

REFERENCES

Atiković, A., & Smajlović, N. (2009). Relation between vault difficulty and bomechanical parameters in men's artistic gymnastics. *Science of Gymnastics Journal, 3*(3), 91-105.

Atiković, A. (2012). New Regression Models to Evaluate the Relationship between Biomechanics of Gymnastic Vault and Initial Vault Difficulty Values. *Journal of Human Kinetics*, *35,* 119-126. doi:10.2478/v10078-012-0085-6

Čepička, L. (2003). Using the Rasch model to improve the qualitative analysis of the overarm throw. *Kinesiology*, *35*(1), 30–35.

Čuk, I., & Karacsony, I. (2004). Vault: methods, ideas, curiosities, history. ŠTD Sangvinčki.

Gervais, P. (1994). A prediction of an optimal perfomance of the handspring 1 l/2 front salto longhorse vault. *Journal of Biomechanics*, *27*(1), 67 -75.

Hanai, Y., & Maeno, N. (2014). Identification of straddle vault movement patterns by Latent class analysis. *Journal of health and medical science, 4,* 49-58.

Hedbávný, P., & Kalichová, M. (2015). Optimization of velocity characteristics of the yurchenko vault. *Science of Gymnastics Journal*, *7*(1),37-49.

Hisamoto, Y., Goto, Y., & Tujino, A. (1986). Kikaiundou no gakusyusidou nikannsuru kisotekikennkyu. *The bulletin of Japanese curriculum research and development*, *11*(1), 25-32. doi: 10.18993/jcrdajp.11.1_25

Hosogoe, J., Nakamura, T., Yonemura, K., & Takahashi, T. (2001). A study on movement tasks as analogon to acquire the skills of the astride vault. *Japanese journal of sport education studies*, *21*(2), 81-92. doi: 10.7219/jjses.21.81

Hedbávný, P., Svobodová, L., & Kalichová, M. (2017). The level of selected gymnastic abilities in elementary school pupils. *Proceedings of the 11th international conference on kinanthropology*, 712-721.

Kaneko, A. (1987). *Kyousi no tameno kikai undou series 1, tobibako heikindaiundou*. Taisyukansyoten.

Kato, K., Kawamoto, C., Ae, M., & Morioka, Y. (2014). Validity of their observational evaluation in forward and backward rolls for elementary school children. *Studies of growth and development*, *64*, 1-10. doi: 10.5332/hatsuhatsu.2014.64_1

Kevin, L., David, S., Stephen, L., & Jacqueline, G. (2013). Age and gender differences in adolescent and adult overarm throwing. *Research Quarterly for Exercise and Sport*, *84*, 239-244. doi: 10.1080/02701367.2013.784841

Koh, M., & Jennings, L. (2007). Strategies in preflight for an optimal Yurchenko layout vault. *Journal of Biomechanics*, 40, 1256-1261.

Kokudo, S. (2017). *Deterioration of the sprint motion caused by adolescent awkwardness for elementary school children.* 22th Annual Congress of ECSS European College of Sport Science.

Kovač, M., & Čuk, I. (2003). Testna naloga za preverjanje praktičnih znanj prizunanjem preverjanju in ocenjevanju znanjaob zaključku devetletne osnovne šole:gimnastika – raznožka čez kozo. [Test task for evaluation of practical skills in external evaluation and assessment of knowledge at the end of primary school: gymnastics –straddle vault over the buck] Ljubljana: Republiški izpitni center.

Laura, J., Heidi, S., Jouni, K., Janne, Ka., Urho M. K & Tuija H. T. (2018). Objectively measured physical activity, body composition and physical fitness: Cross-sectional associations in 9- to 15-year-old children. *European Journal of Sport Science, 18*(6), 882-892. doi:10.1080/17461391.2018.1457081

Linzer, D. A., & Lewis, J. B. (2011). poLCA : An R package for polytomous variable latent class analysis. *Journal of Statistical Software*, *42*(10), 1-29.

Pajek, M., Čuk, I., Kovač, M., & Jakše, B. (2010). Implementation of the gymnastics curriculum in the third cycle of basic school in Slovenia. *Science of Gymnastics Journal*, *2*(3), 15-27.

Kovač, M.,. (2012). Assessment of gymnastic skills at physical education – the case of backward. *Science of Gymnastics Journal*, *4*(3), 25-35.

Masyn, K. (2013). Latent class analysis and finite mixture modeling, *The Oxford Handbook of Quantitative Methods in Psychology*, *2*, 551-611.

Majerič, M., Strel, J., & Kovač, M. (2016). The importance of different evaluation methods in physical education – a case study of straddle vault over the buck. *Science of Gymnastics Journal*, *8*(2), 167-186.

Mills, C. (2005). Computer simulation of gymnastics vault landings.

Ministry of Education. (2017). Course of study at elementary school for PE. Toyokansyuppan.

Miwa, T. (2009). New methods of quantitative analysis (3) An introduction to latent class models. *Sociological theory and methods*, *4*(2), 345-356.

Nakamura, K., Takenaga, R., Kawaji, M., Kawazoe, K., Shinohara, T., Yamamoto, T., Yamagata, Z., & Miyamaru, M. (2011). Development of fundamental motor pattern using the observational evaluation method in young children. *Studies of growth and development*, *51*, 1-18. doi: 10.5332/hatsuhatsu.2011.51_1

Paschalis, K., George, D., Allessandra, D. C., & Giovanni, F. (2015). Knee injuries at landing and take-off phase in gymnastics. *Science of Gymnastics Journal*, *7*(1), 17-25.

Pehkonen, M. (2010). Quality of the teaching process as an explanatory variable in learning gymnastics skill in school physical education. *Science of Gymnastics Journal*, *2*(2), 29-40.

Rudd, J. R., Barnett, L. M., Farrow, D., Berry, J., Borkoles, E., & Polman, R.(2017). The Impact of Gymnastics on Children's Physical Self-Concept and Movement Skill Development in Primary Schools. *Measurement in Physical Education and Exercise Science, 21*(2), 92-100.

Sano, T., Kokudo, S., Kondo, R., Ueda, K., & Kawakatsu, S. (2019). Investigation of the evaluation of proficiency level in straddle-vault movements and teaching points according to the level for elementary school children. *Studies of growth and development*, *84*, 11-22. doi: 10.5332/hatsuhatsu.2019.84_11

Shinohara, T., Nakamura, K., Takenaga, R., Niwa, A., Nagano, K., Masano, Y., & Nakamura, T. (2016). Evaluating the development of rope jumping pattern among children using the observational evaluation method. *Studies of growth and development*, *72*, 1-12. doi: 10.5332/hatsuhatsu.2016.72_1

Takamoto, M., Dei, Y., & Ogata, M. (2003). Development of running, jumping and throwing motion in elementary school children. *Japanese Journal of Sport Education Studies*, *23*(1), 1-15. doi: 10.7219/jjses.23.1

Yamashita, Y. (1996). Zur Bewegungstechnischen Systematisierung der KunststUcke im Gerateturnen. *Annual report of the Faculty of Education, University of Iwate*, *56*(1), 113-122.

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