

Characteristics of Women's Rhythmic Gymnastics from the Perspective of "Body Difficulty" and Performance Time

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Abstract

Tendencies in rhythmic gymnastics were investigated, to obtain basic information about the of performance gymnastics. Participants were gymnasts (N = 27: 22 experienced gymnasts and 5 junior gymnasts) that participated in individual exercises at the 66th Japan rhythmic gymnastics competition. We examined four exercises, hoop, ball, clubs, and ribbons. For each exercise, we recorded the time and the number of "Body Difficulties" and the time taken to execute one Difficulty. Moreover, we recorded the time for each movement. Then, we used these values to examine the reliability and validity of the chronological index of a composition. The correlation between each index and the Difficulty score was calculated for each apparatus. Based on the scoring rules for "Difficulty", the duration of Body Difficulty was defined from preparation to the end of each Difficulty. We conducted a two-way analysis of variance (ANOVA) with the apparatus and movements as independent variables, which indicated a significant interaction effect in the number of Difficulties that were executed. Moreover, there was a significant main effect of apparatus and movement. Furthermore, performance time showed significant interaction effects (all $p < 0.01$). However, no significant interaction was observed for the time for executing each Difficulty.

Keywords

Rhythmic Gymnastics, Execution Time of Body Difficulty, Comparison between Apparatus

1. Introduction

1.1. Rules and Trends of the Rhythmic Gymnastics

Rhythmic gymnastics is a competitive sport in which gymnasts perform to mu-

sic, using different apparatus, by following a pre-determined composition of exercises. The rules for scoring in rhythmic gymnastics are revised every four years after the Olympics. The rules revised in 2013 after the London Olympics, indicated that exercises were to be scored with the maximum 20 points, which accounted for Difficulty and Execution. The Difficulty score (D score) and the Execution score (E score) are each scored with a maximum of 10 points. D score referees compare the Difficulty reported in the Difficulty form and the accuracy of the Difficulty executed in the actual exercise, and then decide the D score. The actual evaluation consists of the Artistic Faults and Technical Faults, and the referees evaluate the exercise from artistic and technical perspectives by subtracting points (Figure 1). The Difficulty of a performance consists of four categories: conventional Body Difficulty, Dynamic Elements with Rotation and Throw, and the newly added Dance Step Combinations that need to last longer than eight seconds, and Mastery of the Apparatus (Figure 2). The Body Difficulty was the object of research, because the Body Difficulty among the four elements making up the D score was the most allocated point and was important. The Body Difficulty consists of three kinds of movements: jump, balance, and rotation (Figure 3).

1.2. The Problem and Purpose

There are two streams of research in the field of rhythmic gymnastics, philosophical studies on the value of rhythmic gymnastics, and applied research on improving competitive abilities. The main focus of research on the value of

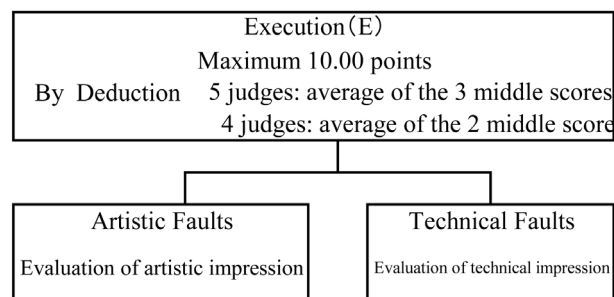


Figure 1. Contents of the E score in individual rhythmic gymnastics.

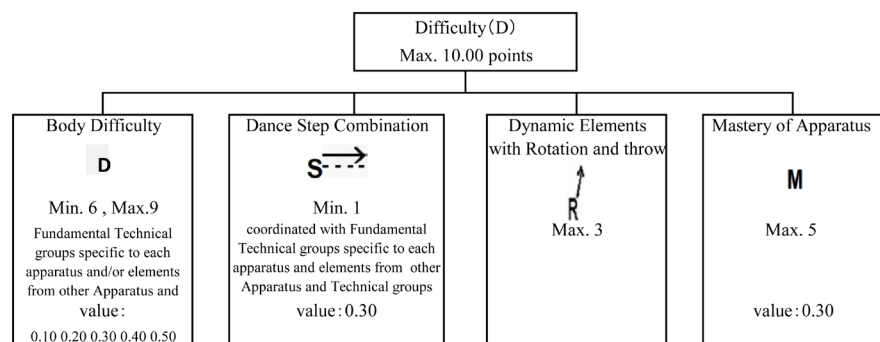


Figure 2. Contents of the D score in individual rhythmic gymnastics.

	Jumps/Leaps Difficulties \wedge	Balance Difficulties \top	Rotation Difficulties \circ
Basic Character	Defined and fixed shape during the flight	Defined and clearly fixed shape (stop position)	Minimum basic rotation of 3600
	Height is sufficient to show the corresponding shape	Executed on the toes, a flat foot, or different parts of the body	Defined and fixed shape during the entire rotation
			Executed on the toes (Pivot), flat foot, or on the support of different parts of the body

Figure 3. Movements in Body Difficulty.

rhythmic gymnastics has been the artistic perception of rhythmic gymnastics. [Uratani \(2012\)](#) and [Uratani \(2014\)](#) investigated evaluation methods of the artistic component based on scoring rules. [Shimazaki \(1979\)](#) organized and reviewed characteristics of rhythmic gymnastics and noted that the future task is to expand and spread rhythmic gymnastics. On the other hand, studies on improving competitive ability in rhythmic gymnastics are broadly divided into two types: research on techniques and those on composition. In technical studies, each technique has been studied by biomechanical analysis of movement characteristics ([Mima, 1998](#); [Kakimoto et al., 2007, 2008](#); [Ono, 2012](#)). Moreover, [Kawano \(2014\)](#) compared items in which points are reduced, by using the “buckle pivot score” as an example, in order to review the evaluation method based on new scoring rules. Research on composition has investigated historical transitions in rhythmic gymnastics, and changes in scoring systems have been compared and analyzed ([Shimazaki, 1979](#); [Takahashi, 2000](#); [Murata, 2011](#)). Furthermore, studies have analyzed movements of gymnasts, categorization based on physical movements, and categorization based on characteristics of apparatus ([Takahashi, 1994](#); [Takahashi, 1998](#); [Sekita, 1994](#); [Kobayashi, 1980](#)). However, studies on techniques have focused on isolated techniques, instead of consecutive movements. In order to improve competitive ability, not only the execution of elements with a high degree of Difficulty, but also the expression of individual characteristics, and uniqueness are essential. Moreover, most studies on composition have only focused on the number of Difficulties, whereas only few studies ([Takahashi, 2011](#)) have focused on the time spent to execute such Difficulties, without investigating the Difficulty, or movements in one set of exercise, or the proportion of time for each element of handling the apparatus. The scoring rules require performing a certain number of Difficulties of various levels, within a limited time. In order to follow such scoring rules, planning the time for each Difficulty within the composition is important. Moreover, contemporary rhythmic gymnastics require a strategic composition. Therefore, incorporating time features in the composition of the exercises and examining the relationship between the composition and the strength of gymnasts from a chronological perspective would be beneficial.

When examining factors affecting the length of the Difficulty, rotation, the increased number of rotations affects the Difficulty score and provides technical points, and increases the time spent for each rotation. Moreover, the position of the upper body and legs affects the D score for balance. When the gymnasts want a high D score by mastering complex apparatus, they must keep the bal-

ance for longer. Furthermore, the jump requires dynamic execution with sufficient height and length. A longer time is required for gymnasts to jump higher and move further during the jump. These points are associated with higher technical levels, which suggest that high technical levels would result in spending a longer time for each Difficulty.

The main goal of the present study was to develop an optimal strategy for the composition of rhythmic gymnastics performances. We analyzed the number of movements and time for executing Body Difficulties of top ranking gymnasts competing in actual competitions in Japan. The purpose of this research is to obtain basic information about the structure of their performance by examining its composition. We particularly examined the relationship between the D score as an index of technical competence and the execution time of Body Difficulty.

2. Method

2.1. Participants and Method

Through competition organizers, we requested female gymnasts ($N = 40$) and their teams that took part in the 66th Japan national rhythmic gymnastics competition, consent for taking and using video images of their performance. These gymnasts were Japan's top level players. Of 40 gymnasts, 27 gymnasts, 22 senior gymnasts and 5 junior gymnasts that were 15 years old or younger, provided consent. We analyzed four types of exercises, Hoop, Ball, Clubs and Ribbon.

2.2. Data Collection and Data Analysis

During the competition, we recorded the 13-meter x 13-meter floor from the camera space reserved for officials, on the second floor. We used a digital video camera (Panasonic, HX-WA20, 29.97fps). The Japan Gymnastics Association provided a permission to record the competition. We played the recorded video frame-by-frame and defined when the gymnasts made the first move as the starting time of the exercise and the analysis was terminated when the gymnast stopped at the end of the exercise. Based on the list of Difficulty, the execution time of a Difficulty was defined from the start of preparation for executing a Difficulty to the end of executing one Difficulty. This analysis was conducted by researcher who qualified for rhythmic gymnastics and experienced rhythmic gymnastics for over 20 years. The validity of the evaluation was confirmed as a pilot survey using another performance which acting configuration was already known.

We examined the reliability and validity of the chronological indices of composition by recording the number and the time of Body Difficulties in one exercise. Moreover, we obtained the execution time by each movements of the Body Difficulty and calculated each index of Body Difficulty and the D score. The D and E scores were obtained from official report of the competition.

3. Results

In this section, first we show reliability and validity of the chronological indices,

second we show the scores, number of difficulty, and execution time.

3.1. Reliability and Validity of the Chronological Indices

We randomly chose three gymnasts and input their data, which consisted of 12 exercises using four apparatus, twice in order to examine the reliability of the data. The resulting ICC (1, 1) indicated 1.00 for the number of Body Difficulty, 0.99 for the time per one Difficulty, 0.99 for total Difficulty time.

3.2. Scores

Table 1 shows mean scores and each index of the Body Difficulty by apparatus. The D Score ranged from 5.2 to 5.4 points, and the E score from 7.2 to 7.3 points, and the penalty ranged from 0.0009 to 0.050. The total score ranged from 12.3 to 12.7 points. We conducted an ANOVA to examine differences in scores between apparatus, which indicated no significant main effect.

3.3. Number of Difficulty

The number of Difficulty ranged from 8.6 to 8.8 that were close to the maximum of 9. An ANOVA indicated no significant main effect observed between apparatus.

We conducted a two-factor ANOVA with apparatus and movement types being within participant factors, which indicated a significant interaction, $F_{6, 156} = 4.91$, $p < 0.01$. The post hoc analysis of simple main effect of the movement revealed that the number of Ribbons was significantly less than other three apparatus for balance. In the jump, the number of Ribbon was significantly more than for Ball and Clubs. Between apparatus comparison indicated that the number of Difficulty in balance was significantly more than jump in the Hoop, and the number of Difficulties in rotation and balance were significantly more than jump for Ball and Clubs. Moreover, significantly more Difficulties in rotation were executed for the Ribbon than for the jump.

Table 1. Scores and the between apparatus comparison of the Body Difficulty.

(n = 27)	H	B	C	R	F	Multiple Comparison
Score						
D Score	5.3 ± 0.8	5.4 ± 0.5	5.2 ± 0.7	5.4 ± 0.6	1.89	
E Score	7.2 ± 0.4	7.2 ± 0.3	7.2 ± 0.5	7.3 ± 0.4	0.54	
Penalty	0.0 ± 0.1	0.0 ± 0.1	0.1 ± 0.1	0.0 ± 0.0		
Final Score	12.5 ± 1.1	12.6 ± 0.8	12.3 ± 1.2	12.7 ± 1.0	1.99	
Body Difficulty						
No. of Difficulty	8.8 ± 0.4	8.8 ± 0.4	8.6 ± 0.7	8.7 ± 0.4	0.65	
Time per one Difficulty (s/No. Difficulty)	4.3 ± 0.4	3.9 ± 0.3	4.5 ± 0.5	4.1 ± 0.5	13.46**	B < H,C; R < C
Performance time (s)	37.7 ± 3.9	33.9 ± 3.3	38.6 ± 5.5	35.8 ± 4.1	9.38**	B < H,C

**, $p < 0.01$ H; Hoop B; Ball C; Clubs R; Ribbon.

We examined and compared the repeatability of movements as a within participant factor. Two gymnasts among 27 executed the identical number of elements for nine Difficulties in four apparatus. Furthermore, 10 gymnasts among 27 engaged in the jump the identical number of times in all four apparatus. The same tendency was observed for three gymnasts in balance and five gymnasts in rotation. On the other hand, six gymnasts indicated complete inconsistency in elements for Difficulties in four apparatus.

3.4. Execution Time

We examined the difference in time to execute one Difficulty and compared the difference as a function of apparatus using an ANOVA. The result indicated significant main effects, and the post hoc multiple comparison analysis revealed that the gymnasts took significantly longer to execute one Difficulty in the Clubs than for the Ball and the Ribbon, with the Hoop being longer than the Ball.

Table 2 shows between apparatus comparison by movements. A two-way ANOVA for execution time for one Difficulty indicated no significant interaction, $F_{6,156} = 0.35$, $p = \text{n.s.}$, but a significant main effect was observed for apparatus, $F_{3,156} = 11.11$, $p < 0.01$, and movements, $F_{2,156} = 36.79$, $p < 0.01$. A post hoc multiple comparison analysis indicated that the Hoop and Clubs took significantly longer than the Ball. For movements, balance took significantly longer time than the jump, and rotation was significantly longer than balance.

The execution time ranged from 33.9 to 38.6 seconds yielding one third of total exercise time for all the apparatus. Examining difference between the apparatus indicated a significant main effect. A post hoc multiple comparison analysis revealed that the execution time was significantly shorter for the Ball than for

Table 2. Between apparatus comparison by movements.

(n = 27)	H	B	C	R
No. of Difficulty				
Rotation	3.0 ± 0.7	3.2 ± 0.6	3.0 ± 0.8	3.3 ± 0.8
Balance	3.2 ± 0.8	3.1 ± 0.7	3.2 ± 0.8	2.6 ± 0.7
Jump	2.6 ± 0.6	2.5 ± 0.5	2.4 ± 0.5	2.8 ± 0.4
Time per one Difficulty (s/No. Difficulty)				
Rotation	5.1 ± 1.1	4.6 ± 0.7	5.0 ± 1.7	5.0 ± 0.8
Balance	4.1 ± 0.7	3.7 ± 0.7	4.2 ± 0.8	3.9 ± 1.0
Jump	3.6 ± 0.7	3.2 ± 0.3	3.7 ± 1.2	3.2 ± 0.5
Performance time (s)				
Rotation	15.0 ± 4.4	14.7 ± 3.4	15.0 ± 7.1	16.5 ± 4.3
Balance	13.3 ± 3.7	11.5 ± 3.8	13.5 ± 3.3	10.3 ± 3.9
Jump	9.2 ± 2.4	7.8 ± 1.5	8.8 ± 4.2	8.9 ± 1.6

H; Hoop B; Ball C; Clubs R; Ribbon.

Hoop and Clubs. A two-way ANOVA indicated a significant interaction for execution time, $F_{6,156} = 2.54$, $p < 0.01$. Therefore, we examined the simple main effect, which indicated that for the difference in the apparatus, the time was significantly longer for the Hoop and the Clubs the Ribbon in balance, with the Club being longer than the Ball. No difference between apparatus was observed for rotation and jump. For the between difference in movements, for all movements, the execution time for balance was significantly longer than for jump, and rotation was significantly longer than balance.

The difference between senior and junior gymnasts was examined by comparing mean values between the two groups. The result indicated that junior gymnasts scored significantly higher points for the D score, senior gymnasts, 5.04 ± 0.67 points, and junior gymnasts 5.83 ± 0.59 points, $t_{25} = 2.41$, $p < 0.05$. Senior gymnasts scored significantly higher points for the Ball penalty, senior gymnasts, 0.05 ± 0.10 points, and junior gymnasts 0.00 ± 0.00 points, $t_{21} = 2.45$, $p < 0.05$. Moreover, 74 exercises consisted of nine Difficulties (84%) and 14 exercises consisted of eight Difficulties (16%) for senior gymnasts. On the other hand, for junior gymnasts, seven exercises consisted of nine Difficulties, (35%) and 12 exercises consisted of eight Difficulties (60%), one exercise six Difficulties (5%). Comparing mean values of these two groups revealed that the score for the Hoop and the Ball were significantly higher for senior gymnasts, the Hoop: senior gymnasts, 8.91 ± 0.29 points, and junior gymnasts 8.20 ± 0.45 points, $t_{25} = 4.42$, $p < 0.01$; Balls: senior gymnasts, 8.91 ± 0.29 points, and junior gymnasts 8.20 ± 0.45 points, $t_{25} = 4.42$, $p < 0.010$. The execution time was significantly longer for senior gymnasts, with the exception of the Hoop, Ball: senior gymnasts, 34.6 ± 3 seconds, and junior gymnasts 31.0 ± 3.3 points, $t_{25} = 2.42$, $p < 0.01$; Clubs: senior gymnasts, 39.7 ± 4.9 seconds, and junior gymnasts 33.8 ± 6 seconds, $t_{25} = 2.32$, $p < 0.05$; Ribbon: senior gymnasts, 36.6 ± 3.9 seconds, and junior gymnasts 32.1 ± 2.7 seconds, $t_{25} = 2.49$, $p < 0.05$. No significant difference was observed for the execution time per one Difficulty.

Rules limit the number of Difficulty for junior competitions to a maximum of seven; however, only one exercise consisted of less than seven Difficulties, and 95% of the exercises, 19 exercises, consisted of eight or more Difficulties. Therefore, junior gymnasts had adjusted their program for this competition and participated in the competition with the same standard as senior gymnasts. We compared the scores of senior and junior gymnasts, which indicated that junior gymnasts scored significantly higher D scores in the Clubs, whereas other apparatus showed no significant differences. Furthermore, junior gymnasts had significantly lower penalties in the Clubs, whereas there were no significant differences in other apparatus. Since the junior gymnasts performed at a high level as senior gymnasts, and their techniques were evaluated to be identical, we conducted the following analyses treating junior and senior gymnasts as one group.

3.5. Elements of the Body Difficulty and the D Score

Table 3 shows the correlation coefficients between each variable and the D

score. A significant correlation was observed between the execution time per one Difficulty and the D score, $r = 0.457$, $p < 0.05$; however, no significant correlation was observed for other variables. **Table 4** shows correlation coefficients between each index of movements and the D score. For rotation, the D score was positively correlated in the Clubs with the execution time per one Difficulty and the execution time. For balance, the D score was positively correlated with the number of Difficulty and the execution time in Hoop. Moreover, negative correlations were observed in the jump for the number of Difficulty and the execution time per one Difficulty for all four apparatus. Significant negative correlation was found in Clubs for the execution time for one Difficulty and the total execution time. Furthermore, execution times for the Hoop and the Ribbon indicated significant negative correlations.

4. Discussion

4.1. Examination of Scores

The average penalty points of participants in the present study were less than 0.05, and the total score was nearly equal with the addition of D and E scores. Penalties includes reductions in the score for breaking rules, such as going over

Table 3. Correlation between the D score and each variable.

(n = 27)	H	B	C	R
No. of Difficulty	-0.125	0.004	0.052	-0.069
Time per one Difficulty	-0.047	0.077	-0.457*	0.157
Performance time	-0.095	0.062	-0.340	0.135

*, $p < 0.05$; H; Hoop B; Ball C; Clubs R; Ribbon.

Table 4. Correlation between the D score and the movements by apparatus.

(n = 27)	H	B	C	R
No. of Difficulty				
Rotation	-0.250	-0.053	-0.101	0.052
Balance	0.385*	0.060	0.283	0.093
Jump	-0.289	-0.016	-0.203	-0.331
Time per one Difficulty (s/No. Difficulty)				
Rotation	0.037	0.153	0.494*	0.120
Balance	0.036	-0.024	-0.175	0.187
Jump	-0.252	-0.018	-0.404*	-0.090
Performance time (s)				
Rotation	-0.226	0.022	0.398*	0.119
Balance	0.407*	0.050	0.136*	0.179
Jump	-0.431*	-0.040	-0.424*	-0.408*

*, $p < 0.05$; **, $p < 0.01$; H; Hoop B; Ball C; Clubs Ribbon.

the time limit, the body, or the apparatus reaching outside the field, and using spare apparatus. Penalties often occur in competitions early in the season, or in regional competitions for juniors and children. They decrease, as perfection is achieved. Therefore, it can be concluded that participants in the present study exercised at a high level.

The score per one apparatus ranged from 12.300 to 12.700 points, with the highest score being 15.600. Moreover, the total score for all four apparatus ranged from 39.100 to 61.300 points out of a maximum of 80 points. Top gymnasts in international competitions usually score around 18 points for one apparatus. At The World Championship in 2013, Yana Kudryavtseva broke the world record by scoring 18.700 points in the Clubs and 73.866 points for all four apparatus. The participants in the present study scored far below the world standards, and were at a low level compared to international gymnasts. The participants in the present study scored 7.2 to 7.3 points in the E score, whereas the E scores of top gymnasts in the World Championship are over 9 points for all four apparatus. The E score is different from the score deducted for penalties, and it reflects mistakes during the exercises, such as dropping the apparatus, lack of beauty in hand and toe movements, inaccurate execution of Difficulties, and lack of control in handling the apparatus. Techniques with low Difficulty can easily result in high points, because details including body movements and handling the apparatus can be conducted well. On the other hand, difficult techniques tend to elicit mistakes. The gymnasts in the present study seemed to have attempted Difficulties with higher techniques than permitted by their actual skills.

The D scores for top gymnasts in World Championships were 9 points for all four apparatus, whereas scores of gymnasts in the present study ranged from 5.2 to 5.4 points. Although they executed approximately nine Body Difficulties, their scores were approximately half that of top gymnasts, because no additional or partial points were given for the D scores. Of particular, if a gymnast does not complete the Body Difficulty, no points are given. In our study, it is possible that the executed Difficulties were inaccurately scored as zero. Therefore, the low score of participants in the present study might be attributed to attempting to achieve high Difficulty points, since their task was to execute high difficulty, but their performance was incomplete resulting in zero points. As a result, the D scores were significantly low as compared to international scores. We examined videos of participants in the present study, which indicated that the addition of rotation and waves before and after the Difficulty, and the addition of new factors such as changing rotation types and dynamic factors with rotation and throwing interfered with the flow of the exercises, which lacked smoothness between Difficulties. Smooth exercises are essential for D and E scores to increase to nine points. Furthermore, it is important to overcome technical issues, such as quickness of Body Difficulty. However, the main purpose of the present study was to examine the tasks to develop the composition of the program. Therefore, technical issues are not discussed any further.

4.2. Examination of the Number of Difficulties

Body Difficulty ranged from 8.6 to 8.8 points for one apparatus. Since six to nine Body Difficulties are required for senior competitions, the official Difficulty form possibly listed less than nine Difficulties. However, in the current scoring system, in which points are added for the execution of Difficulty, gymnasts would hardly declare less than nine Difficulties. Therefore, there should be un-evaluated Difficulties due to execution failures. Actually, eight exercises yielding 16% of all the exercises were executed with less than nine Difficulties by senior gymnasts. Examining these eight exercises revealed apparent failures, such as stopping the exercise because the gymnasts dropped the apparatus. Therefore, it can be assumed that there were nine Difficulties in the official form, but athletes did not execute all of them during their performance. Moreover, the analysts were women with second-degree referee certification in rhythmic gymnasts, and their reliability was high as indicated by the inter-rater reliability. Thus, over-seeing the Difficulty was unlikely. However, the official forms that had been turned in before the competition are not open to public, and it is impossible for us to confirm the content of the form. Therefore, it might be possible that we miscalculated the number of Body Difficulty.

Examining the relationship between movements and apparatus for number of Body Difficulty indicated that rotations were executed as the largest number of Body Difficulty in Ball and Ribbon, and balance was executed as the largest number of the Body Difficulty in the Hoop and Clubs. The jump was executed the least number of the Body Difficulty among all four apparatus other than the Ribbon. The rules prior to 2013 revision had designated the types of movements required to be incorporated for each apparatus; flexion for the Ball, balance for Clubs, and pivots for the Ribbons have been designated as the main movements in the exercise. Moreover, all the skills were required to be evenly incorporated for the Hoop. Nonetheless, these rules have been discarded, and new compositions require incorporating all movements evenly from the Body Difficulty for all the apparatus. However, the participants in the present study tended to present the same type of composition before the 2013 revision showing a failure to adopt the new rules. It is possible that gymnasts decide on the number of Body Difficulty, based on their technical strength and character. Therefore, we examined within subjects repeatability of three movements. The results indicated that two among 27 gymnasts performed exactly the same nine Body Difficulties with all four apparatus. Moreover, 10 out of 27 gymnasts did the same number of jumps with all the apparatus. On the other hand, six gymnasts did completely differently exercises with all four apparatus. These results suggest that some gymnasts strategically decided on the distribution of Body Difficulty. In addition to the character of each movement, we need to consider how to benefit from Body Difficulty as a personal strength.

4.3. Comparison of Execution Time between Apparatus

For the first time, the present study quantitatively evaluated execution time of

Body Difficulty. Results indicated that execution time of Body Difficulties consists of 30 to 40 seconds of a 90-second exercise program. The execution time was related to the execution time per one Difficulty and the number of Difficulties. Until 2001, the number of Difficulties was unlimited. However, a maximum limit for the number of Body Difficulties was set when the official declaration form was first used in 2001. Furthermore, an eight-second dance step combination was newly added to the D score category in 2013 shortening the time spent on Body Difficulty. On the other hand, the 2013 revision included additional points for rotations, walkovers, and full body waves before and after Difficulties, increasing the time spent on each Difficulty. Therefore, after 2001, the execution time has become shorter in terms of the number of Difficulties, whereas the time per one Difficulty has become longer.

The comparison of execution times between apparatus indicated that time spent for the Ball was shorter than for other apparatus. The number of Difficulties did not differ between apparatus, therefore, this could be due to the short time spent for one Difficulty. The reason why the execution time for the ball was shorter than for other apparatus could be due to the nature of handling the ball. It is necessary to handle the apparatus in order to gain points for Body Difficulty and handling an apparatus that is conducted simultaneously with Body Difficulty affects execution time. Holding the ball in the hands is considered unstable balancing, qualifying it as handling the apparatus. Thus, the Ball requires less complex handling. Moreover, the process after handling the apparatus is brief and requires less time. Therefore, the Ball has a shorter execution time per one Difficulty. When developing a composition, gymnasts can take advantage of characteristics of the apparatus and manage the structure of Body Difficulties and strategically incorporate other factors. This is especially true for the Ball, for which handling the apparatus and the flow of the apparatus can be taken into consideration.

4.4. Comparison of Execution Time between Movements

Comparing the execution time between three movements requires using the time for one Difficulty, because items in number of Difficulties for each movement are different. As a result of comparing between execution time per one Difficulty, rotation took approximately five seconds, which was the longest time, it was followed by the balance, which took four seconds, followed by the jump, which took the shortest time of three seconds. In rotation, the correlation between the D score and each variable by three movements showed a significant positive correlation for only the Clubs, whereas other apparatus did not have a significant relationship with the D score. For balance, the execution time for the Hoop and the D score had a significant positive correlation, but other apparatus did not show a significant relationship. Moreover, the Hoop, which had a significant relationship with the number of Difficulty, was not correlated with the time per one Difficulty. Moreover, all correlation coefficients for the Jump were negative, and the correlation with Clubs was significant. These findings indicate

that for these Difficulties, there were no positive correlations between the D score and time per one Difficulty. This finding indicates that gymnasts with a high D score and high technical ability do not necessarily spend a long time to execute one Difficulty.

There are three reasons why the D scores might not be related to execution time. First, the speed of the motion and the time taken for preparation are affected by the amount of muscles and the technical skills of a gymnast. The Difficulty of rotation increases by the number of rotations with the fixation at the rotation posture, or for maintaining body posture. Gymnasts with high technical skills are assumed to rotate fast, and they can take the rotation posture in a shorter time, resulting in shorter times for on Difficulty, regardless of the high number of rotations. The balance requires completing certain actions with the apparatus, and legs and the upper body being stabilized at a designated position. The time spent at the stop position becomes shorter for experts that are able to handle the apparatus quickly. Moreover, the transition of weight by the supporting leg at preparation and bringing back the legs can be done quickly with expertise, which results in a shorter time to execute the Body Difficulty. The Jump requires split legs, sufficient height, and an accurate upper body position, and the gymnast can jump once, or jump consecutively up to three times. Multiple jumps with sufficient height and splits, shortens the time for the *chassé* and hop, which is a run up period for acceleration leading to a shorter time per one Difficulty.

The second reason is the achievement of Difficulty with many rotations. Multiple rotations are defined as two or more rotations within one Difficulty. During the rotation, the heel of axial leg needs to move up and down, and the other leg repeats horizontal kicks. Moreover, the Italian *fouetté* requires balancing the body in different positions up to three times, without changing the axial leg. However, if the axial leg is unbalanced during multiple rotations or balancing, inaccurate body positions, transition of axial legs, and lack of rotation angle could be present, and the D score might not be granted. In the present study, 19 gymnasts, or 70% of the gymnasts incorporated multiple rotations. Of these, 15 gymnasts, or over 50% of the gymnasts declared the Italian *fouetté*. They seemed to continue performing rotations and balances for no points. Therefore, despite the long time for the Difficulty no D score was given for rotation and balance.

At last, there is the possible addition of a D score, other than for Body Difficulty. D score is the total points obtained in four categories, only the Body Difficulty, but also mastering the apparatus. Since the content of the four categories are complex, we do not discuss the detail of scoring criteria. In order to perform Body Difficulty, the simultaneous apparatus mastery is mandatory. Inaccurate use of the apparatus results in zero points for Body Difficulty.

5. Conclusion

In this study, a new index, consisting of a chronological perspective to analyze execution time and the number of Difficulties that is the subject of technical

evaluation, was introduced. Secondly, we examined the execution time and the number of Difficulties, by comparing movements (jump, balance, and rotation) and the apparatus, and the results indicated characteristics of Body Difficulty. The new index suggested preparation time for movements, and the effects of each apparatus caused by the rules prior to 2013 was identified. Thirdly, the total execution time for executing Body Difficulty by participants of the present study ranged from 30 to 40 seconds. These results suggest that: 1) it is important to consider the number of Difficulties for each coach and the gymnast, in accordance with competition rules; 2) executing isolated Difficulties with a high score, and quick preparation to shorten the time of each Difficulty would enable gymnasts to execute other Difficulties as a way to improve the D score; 3) among beginner level gymnasts and particularly junior gymnasts, it is effective to confirm the validity of a composition from the chronological perspective; 4) the relationship between Body Difficulty and apparatus handling; 5) the importance of strategic thinking from a novel point of view, such as analyzing the time proportion of Difficulty in the exercise. In the future, increasing the number of participants in different age groups and levels would enable us to establish an index for measuring the validity of compositions.

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