METHODOLOGICAL ASPECTS REGARDING THE IMPROVEMENT OF TSUKAHARA VAULT (TEMPO)

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Abstract. *The main purpose of this research is to analyse methodological aspects regarding the improvement of the handspring forward with ½ turn (180^0) in the longitudinal axis, which is known as Tsukahara vault (tempo), for junior gymnasts (levels 2 and 3) aged 10-11 years. The analysed aspects are the basis of an experimental study carried out at the "Steaua" School Sports Club in Bucharest. The study was conducted with a single experimental group consisting of eight female gymnasts selected from the advanced and competitive groups (Women's Artistic Gymnastics section). The athletes were assessed at the beginning of the research (initial testing) and at the end of the experiment after applying a specific programme aimed at both physical training and technical training. Among the physical tests applied, we mention: 25 m sprint, Sargent test, standing long jump, but the assessment also targeted back and shoulder girdle muscle strength, abdominal strength and the ability to maintain specific positions in vault phases (first and second flights). From a technical point of view, the gymnasts' performance was evaluated taking into account the specific penalties provided by the International Gymnastics Federation Classification Programme and the requested positions for the 3 vault phases specified in the Code of Points. The objective of this experiment is to highlight how the improvement of physical and technical parameters influences the accuracy and efficiency of execution.*

Keywords: *artistic gymnastics, Tsukahara, physical training, technical training, performance.*

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Introduction

The Tsukahara vault was named after Mitsuo Tsukahara, a Japanese gymnast who first performed it in 1972. The vault consists of a springboard take-off, a first quarter turn in the pre-flight phase, a push off from the vault table followed by a Corbett action and a salto with longitudinal/transversal turn. Preparation for this vault includes, in addition to technical training, a substantial part of physical training. For the physical training of athletes, a combined strength development method can be used, which integrates a part aimed at developing maximum strength and a part aimed at developing explosive power. To achieve an improvement in sports performance, it is very important to understand the relationships that are established between the various components of speed, strength and muscle fibre

stretch-shortening cycle during sprints or jumps (Ranisavljev et al., 2019). Maximum strength is considered an essential component for increasing speed and jumping performance, especially through plyometric training (Matić & Ranisavljev, 2018). In order to efficiently track performance improvement over a period of time and determine the effectiveness of training programmes, strength must be assessed on a regular basis (Kraemer et al., 2001). Plyometric training is regarded as a very effective tool used to increase sports performance (Ramirez-Campilio et al., 2015).

Many scientific studies point out that this type of training is highly effective for increasing explosive power, especially in terms of acceleration, jumping and sprinting abilities. For example, Loturco et al. (2015) emphasise that plyometric training manages to transfer all neuromuscular gains towards increasing acceleration, jumping and sprinting performance. The same authors show that the use of horizontal jumps during training has a strong effect on the ability to accelerate, while the use of vertical jumps has a great impact on increasing the jump height.

Individual sports are divided into seven groups. The third category is that of technical and aesthetic sports, which include artistic gymnastics, dance and fitness. Verkhoshansky and Siff (2009) claim that the physical training model for these sports incorporates: explosive power, speed, coordination and endurance. The execution of acrobatic elements largely depends on the development of explosive power, which is why it is a crucial criterion in the selection model for these sports. Explosive power is very important in artistic gymnastics because, if its level is not sufficiently high, athletes are not able to correctly perform certain technical elements.

According to the literature (Viru et al., 1999), there are critical periods during childhood and adolescence when explosive power can be successfully developed. Children aged between 12 and 15 years respond very well to explosive power training (Lloyd et al., 2012), but it should be mentioned that this process must start earlier in gymnastics. In terms of explosive power development, there are positive adaptations to the jump height (Meylan & Malatesta, 2009), maximum running speed (Kotzamanidis, 2006) and the rate of strength development (Matavulj et al., 2001).

In women's artistic gymnastics, the height of the jump is extremely important for the successful execution of acrobatic elements, therefore the improvement of jumping skills is essential. Mlsnová and Luptáková (2017) recommend using plyometric exercises combined with maximum strength exercises to increase the level of jumping skills, which are decisive for achieving performance in technical sports such as artistic gymnastics.

The main *purpose* of this research is to show that the improvement of relevant physical qualities (strength, speed, power) and compliance with a methodology based on biomechanical principles can greatly increase the vault parameters in terms of flight path, height, length, time and landing in the second flight phase, thus leading to better execution.

Methodology

Participants

The research participants were 8 female gymnasts aged 10-11 years (junior levels 2 and 3) from "Steaua" School Sports Club in Bucharest, representing the experimental group.

Measurements

Technical testing consisted in performing two Tsukahara vaults (tempo); each athlete received a score calculated by a panel of national judges. Technical execution was evaluated by judges according to the Code of Points (CoP) of the International Gymnastics Federation (FIG, n.d.).

Physical testing included:

- 25 m sprint – the gymnast had 3 attempts, and the best result was recorded; measurements were made in seconds (the objective was to assess speed);
- Sargent test – the gymnast had 3 attempts, and the best result was recorded; measurements were made in centimetres (the objective was to assess power-speed);
- Standing long jump – the gymnast had 3 attempts, and the best result was recorded; measurements were made in centimetres (the objective was to assess power-speed and coordination);
- Deep squats on the right leg - the gymnast performed deep squats on the right leg for 1 minute; measurements were made in number of repetitions;
- Deep squats on the left leg - the gymnast performed deep squats on the left leg for 1 minute; measurements were made in number of repetitions;
- Arm lifts - from standing, body bent at 90 degrees with a weight of 5 kg, the gymnast performed forward arm lifts for 1 minute; measurements were made in number of repetitions (the objective was to assess speed-strength, endurance, speed-endurance);
- Shoulder extension - from standing, body bent at 90 degrees with a weight of 5 kg, the gymnast performed shoulder extension for 1 minute; measurements were made in number of repetitions (the objective was to assess speed-strength, endurance, speed-endurance);
- Upper body lifts - from upside-down hanging on a wall bar, legs leaning against a curved bench, the gymnast performed upper body flexion upon the legs for 1 minute; measurements were made in number of repetitions (the objective was to assess speed and endurance);
- Leg raises - from hanging on a wall bar, back leaning against a curved bench, the gymnast performed leg flexion upon the upper body for 1 minute; recordings were made every 60 seconds, and measurements were made in number of repetitions (the objective was to assess speed and endurance);
- Upper body extension - from front support on the vault table, with legs secured by the coach/ a partner, the gymnast performed upper body extension upon the legs for 1 minute; measurements were made in number of repetitions (the objective was to assess strength - speed and endurance);

- Leg extension - from front support, holding tight on the vault table, the gymnast performed leg extension upon the upper body for 1 minute; measurements were made in number of repetitions (the objective was to assess strength - speed and endurance);
- Handstand hold - its duration was timed, and the result was measured in seconds.

Procedure

Based on the requirements of the National Classification Programme, the Code of Points for Artistic Gymnastics (FIG, n.d.) and the National Technical Programme, the experiment involved two testing sessions in which participants performed two Tsukahara vaults (tempo) and received scores calculated by a panel of national judges. The initial test took place in the training hall of the School Sports Club, and the final test was scheduled two months later in the same location, in the same conditions and with the same panel of judges.

The gymnasts were also tested according to the FIG Physical Testing Charts to assess the speed, strength, power and endurance of relevant muscle groups during the initial test and after two months of training (according to the physical and technical programme proposed by us) during the final test.

Training programme

Physical training programme for the development of lower limb strength

The strategy used for the development of lower limb strength (as a methodological approach) consisted in combining maximum strength development training with 2 sets of exercises for the development of explosive power (plyometric exercises) (Hantău, 2011).

The programme used for strength development is shown in Table 1.

Table 1. *Strength development programme*

	Monday
Intensity	8 x 60%; 6 x 70%; 4 x 80%
Number of repetitions	2 x 90%; 1 x 100%
Sets	2
Execution speed	Uniformity and constancy in the contraction and relaxation phases
Rest between sets	4 minutes

The exercises proposed for this programme included calf and ankle extension and flexion. Moreover, the squat press machine was also used.

Given that the body adaptation to any load occurs within several weeks, the interval for maximum strength testing was established at 3 weeks. The maximum strength assessment method was as follows (Hantău, 2011):

- the load was applied to randomly selected exercises;
- the athlete repeated at a constant speed (in the contraction and relaxation phases) until they were no longer able to perform;
- the number of repetitions was counted;

- the number of repetitions and the load were entered in the following formula:
  maximum strength = number of kilograms/1.0278 – (number of repetitions x 0.0278).

The plyometric programme was used twice a week and consisted of various jumps with one and two legs (Table 2).

Table 2. *Plyometric programme*

Days	Exercises	Repetitions	Sets
Wednesday	CMJ over 35 cm hurdles	8	3
Saturday	CMJA over 45 cm hurdles	8	3
	Jumps over 20 cm hurdles (left leg)	8	3
	Jumps over 20 cm hurdles (right leg)	8	3
	Alternate jumps to the right and left with the right leg over the gymnastics bench	8	3
	Jumps as above with the left leg	8	3
	Jumps as above with both legs	8	3
	Frog jumps	10	3

Note. CMJ – Counter Movement Jump, CMJA – Counter Movement Jump with Arms

Abdominal physical training programme

Abdominal muscle training involved 3 sessions per week, the second training on the same days as plyometric and power training days as follows:

- From hanging on a wall bar, the gymnast performed leg raises upon the upper body, 2 sets of 15 and 10 repetitions, respectively, for 3 weeks; after this period, in the next 3 weeks, the number of repetitions increased to 20 and 15, respectively, and finally, in the last 3 weeks of the programme, the gymnast added small loads to their ankles (250 gr per leg), keeping the same number of repetitions as in the last period (20 and 15);

- From upside-down hanging on a wall bar, hands held behind the head, back leaning against a curved bench, the gymnast performed upper body lifts towards the legs.

The above exercises are performed at the same time throughout the week, with the same number of series and number of repetitions, by applying the same procedure. The same load (500 gr) will be held in front of the chest in the last 3 weeks of the programme;

- From lying sideways on a firm foam block with the upper body unsupported and legs secured by the coach/ a teammate, the gymnast performed 2 series of lateral upper body lifts; the number of repetitions for the first series was 15 and 10, respectively, in the first 3 weeks, 20 and 15, respectively, in the next 3 weeks, and then the same number of series and repetitions as in the previous period was performed with a 500 gr extra load in the last 3 weeks;

- From lying down on the floor, the gymnast raised the opposite leg and arm vertically at the same time (abdominal oblique muscles); 2 series of 20 repetitions in the first 3 weeks, and then, from the same position with legs at 90 degrees, the gymnast performed alternate upper body lifts towards the right and then the left leg for another 3 weeks, and finally, in the last 3 weeks, from the same position as the last one, slowly lowered the legs alternately (once the right leg and once the left leg) until they touched the floor, keeping the same 90-degree angle between the legs and the upper body with shoulders down on the floor.

Back and arm/shoulder physical training programme

- Handstand hold - 3 series of 30, 20 and 10 seconds;
- Handstand walks - 2 lengths forward, 2 lengths sideways and 1 length backwards;
- Handstand block - 3 series of 5 repetitions, take-off on the floor and, after hand repulsion, landing on a 10 cm mat; the same with 90-degree turn, and then with 180-degree turn;
- From handstand, with legs secured by the coach/ a teammate, shifting weight from the right to the left hand by raising the free arm to touch the leg - 2 series of 10 repetitions;
- Straddle position from forward roll - 2 series of 10 repetitions;
- From front support, holding tight on the vault table, the gymnast performed leg extension upon the upper body - 2 series of 25 and 15 repetitions, respectively;
- From front support on the vault table, with legs secured by the coach/ a partner, the gymnast performed upper body extension upon the legs - 2 series of 25 and 15 repetitions, respectively.

The programme was applied two days per week, on the other two days when no plyometric and abdominal training was performed. The number of repetitions and the number of series or the rest time between series were adapted to the progress of each individual gymnast every 3 weeks in order to achieve maximum results.

Results

According to the preliminary data analysis, the results obtained by gymnasts in the physical and technical tests did not indicate excessive (marginal or extreme) values.

In order to compare the initial results with the final scores achieved after the experimental intervention by taking into account all the tests performed by the research participants, the Student's t-test for two dependent samples was used. The condition for applying this test was met, in the sense that the normal distribution of the dependent variable was ensured in both the test situation (initial testing) and the posttest situation (final testing). This condition was verified using the Skewness index of asymmetry and the Kurtosis index of flatness, which fell within the range of ± 1.96 (Predoiu, 2021).

Table 3. *Results for Deep squats on the right leg (R), Deep squats on the left leg (L), Arm lifts and Shoulder extension*

Test results	**Deep squats R 60'**		**Deep squats L 60'**		**Arm lifts 60'**		**Shoulder extension 60'**	
	Initial test	Final test	Initial test	Final test	Initial test	Final test	Initial test	Final test
1	17	28	18	21	27	33	25	34
2	16	27	21	25	29	37	24	36
3	10	19	17	21	16	27	18	26
4	19	30	22	27	32	38	26	34
5	10	18	22	26	12	24	18	27
6	21	30	18	22	37	38	31	38
7	14	27	17	23	25	33	22	36
8	21	31	24	28	32	39	31	42
t	-18.33		-13.56		-6.17		-11.60	
p	0.00		0.00		0.00		0.00	

Note. Values are statistically significant at $p < 0.05$.

Applying the Student's t-test to the tests presented in Table 3 (Deep squats on the right leg, Deep squats on the left leg, Arm lifts, Shoulder extension), it can be noted that there are statistically significant differences (p = 0.00) between the results obtained by gymnasts in the initial assessment and their results after the experimental intervention.

Table 4. *Results for Upper body lifts, Leg raises, Upper body extension and Leg extension*

Test results	**Upper body lifts 60'**		**Leg raises 60'**		**Upper body extension 60'**		**Leg extension 60'**	
	Initial test	Final test	Initial test	Final test	Initial test	Final test	Initial test	Final test
1	26	34	26	37	32	44	18	34
2	24	36	23	36	27	36	18	32
3	21	29	28	35	14	25	15	28
4	29	38	25	37	31	39	19	34
5	14	26	11	24	15	28	16	28
6	31	38	27	38	26	38	20	40
7	22	36	20	29	22	34	16	29
8	28	37	29	38	32	43	21	40
t	-11.28		-14.08		-18.40		-14.79	
p	0.00		0.00		0.00		0.00	

Note. Values are statistically significant at $p < 0.05$.

Applying the Student's t-test to the tests in Table 4 (Upper body lifts, Leg raises, Upper body extension, Leg extension), statistically significant differences (p = 0.00) are noted between the scores obtained by gymnasts in the initial assessment and their final scores.

Table 5. *Results for Handstand hold, Standing long jump, Sargent test and 25 m sprint*

Test results	**Handstand hold (s)**		**Standing long jump (cm)**		**Sargent test (cm)**		**25 m sprint (s)**	
	Initial test	Final test	Initial test	Final test	Initial test	Final test	Initial test	Final test
1	14'	21'	140	157	28	36	5.5	5.1
2	8'	19'	139	148	31	39	5.4	5.0
3	0'	12'	139	151	28	37	6.5	5.8
4	7'	16'	137	148	30	38	6.2	5.7
5	0'	13'	130	142	26	34	6.4	5.7
6	12'	21'	145	155	30	39	5.4	4.7
7	6'	15'	149	160	31	40	5.7	4.8
8	14'	26'	155	167	31	40	5.1	4.5
t	-14.12		-13.99		-44.95		10.03	
p	0.00		0.00		0.00		0.00	

Note. Values are statistically significant at $p < 0.05$.

Applying the Student's t-test to the tests presented in Table 5 (Handstand hold, Standing long jump, Sargent test, 25 m sprint), it can be seen that there are statistically significant differences (p = 0.00) between the results obtained by gymnasts in the two testing sessions.

Results obtained for execution (initial and final testing)

Execution scores were calculated for each participant starting from 10 points, and the final score was the average of the scores awarded by the three national judges.

Table 6. *Results for technical execution*

	Technical execution	
Participants	**Initial test**	**Final test**
1	8.40	9.00
2	8.10	8.70
3	7.80	8.40
4	8.00	8.80
5	7.50	8.10
6	8.40	9.00
7	8.10	8.60
8	8.70	9.20
t	-18.33	
p	0.00	

Note. Values are statistically significant at $p < 0.05$.

In terms of technical execution, it can be observed (Table 6) that there are statistically significant differences ($p = 0.00$) between the results obtained by gymnasts in the initial evaluation and their results after the experimental intervention.

Using the Spearman correlation, we checked whether there were correlations between the scores obtained for physical tests (Deep squats R, Deep squats L, Arm lifts, Shoulder extension, Upper body lifts, Leg raises, Upper body extension, Leg extension, Handstand hold, Standing long jump, Sargent test, 25 m sprint) and those obtained for the technical execution test.

The conditions for applying the Spearman correlation were fulfilled (Labăr, 2008): both variables were ordinal or one of them was quantitative and the other ordinal; the sample was small ($N = 8$); the scores of a variable were monotonously related to the scores of the other variable, meaning that as the values of one variable increased, the values of the other variable also increased (decreased) but not necessarily in a linear manner.

Table 7. *Initial results for physical tests and technical execution – Spearman correlation*

Variables	**N**	**m**	**s**	**Technical execution Spearman's rho correlation coefficient**
Technical execution	8	8.12	0.37	1.000
Deep squat R	8	16	4.40	0.811*
Deep squat L	8	19.8	2.69	0.141
Arm lifts	8	26.2	8.44	0.691*
Shoulder extension	8	24.3	5.04	0.811*
Upper body lifts	8	24.3	5.42	0.675
Leg raises	8	23.6	5.85	0.554
Upper body extension	8	24.8	7.25	0.745*
Leg extension	8	17.8	2.10	0.750*
Handstand hold	8	7.62	5.60	0.933**
Standing long jump	8	141.75	7.72	0.842*
Sargent test	8	29.3	1.84	0.550
25 m sprint	8	5.77	0.52	-0.897*

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Analysis of the results shown in Table 7 highlights that:

- There is a statistically significant positive correlation (0.811) between the initial results for Deep squats R and the initial results for technical execution ($p < 0.05$).

An appropriate indicator for the effect size index is the coefficient of determination (r^2), which has the value 0.65. We can say that 65% of the variation of the two variables is common, the rest being due to other influences. This means that the relationship between the initial results for Deep squats R and the initial results for technical execution is very strong.

- There is a significant positive correlation (0.691) between the initial results for Arm lifts and the initial results for technical execution ($p < 0.05$).

The coefficient of determination (r^2) has the value 0.47, meaning that the relationship between the initial results for Arm lifts and the initial results for technical execution is strong.

- There is a significant positive correlation (0.811) between the initial scores for Shoulder extension and the initial scores for technical execution ($p < 0.05$).

The effect size index has the value 0.65, meaning that the relationship between the initial scores for Shoulder extension and the initial scores for technical execution is very strong.

- There is a significant positive correlation (0.745) between the initial scores for Upper body extension and the initial scores for technical execution ($p < 0.05$).

The coefficient of determination (r^2) has the value 0.55, meaning that the association between the initial scores for Upper body extension and the initial scores for technical execution is very strong.

- There is a statistically significant positive correlation (0.750) between the initial results for Leg extension and the initial results for technical execution ($p < 0.05$).

The effect size index has the value 0.56, which means that the relationship between the initial results for Leg extension and the initial results for technical execution is strong.

- There is a significant positive correlation (0.933) between the initial scores for Handstand hold and the initial scores for technical execution ($p < 0.01$).

The coefficient of determination (r^2) has the value 0.87, which shows that the association between the initial scores for Handstand hold and the initial scores for technical execution is very strong.

- There is a significant positive correlation (0.842) between the initial scores for Standing long jump and the initial scores for technical execution ($p < 0.05$).

The coefficient of determination (r^2) has the value 0.70, which shows that the association between the initial scores for Standing long jump and the initial scores for technical execution is very strong.

- There is a statistically significant negative correlation (-0.897) between the initial results for 25 m sprint and the initial results for technical execution ($p < 0.05$).

The effect size index, in the case of a statistically significant negative correlation (r^2), has the value 0.80, meaning that the association between the initial results for 25 m sprint and the initial results for technical execution is very strong.

- No correlations are found between the initial results for Deep squat L, Upper body lifts, Leg raises, Sargent test and the initial results for technical execution ($p > 0.05$).

Table 8. *Final results for physical tests and technical execution – Spearman correlation*

Variables	N	M	s	Technical execution Spearman's rho correlation coefficient
Technical execution	8	8.72	0.35	1.000
Deep squat R	8	26.2	5.00	0.939**
Deep squat L	8	24.1	2.74	0.175
Arm lifts	8	33.6	5.55	0.849*
Shoulder extension	8	34.1	5.35	0.733*
Upper body lifts	8	34.2	4.43	0.685
Leg raises	8	34.2	5.06	0.945**
Upper body extension	8	35.8	6.70	0.898*
Leg extension	8	33.1	4.88	0.963**
Handstand hold	8	17.8	4.73	0.952**
Standing long jump	8	153.5	7.91	0.627
Sargent test	8	37.8	2.10	0.442
25 m sprint	8	5.16	0.50	-0.687

** Correlation is significant at the .01 level (2-tailed).
* Correlation is significant at the .05 level (2-tailed).

Analysis of the results shown in Table 8 emphasises that:

- There is a statistically significant positive correlation (0.939) between the final results for Deep squats R and the final results for technical execution ($p < 0.01$).

The coefficient of determination (r^2) has the value 0.88, which means that the relationship between the final results for Deep squats R and the final results for technical execution is very strong.

- There is a significant positive correlation (0.849) between the final scores for Arm lifts and the final scores for technical execution ($p < 0.05$).

The coefficient of determination (r^2) has the value 0.72, meaning that the association between the final scores for Arm lifts and the final scores for technical execution is very strong.

- There is a significant positive correlation (0.733) between the final scores for Shoulder extension and the final scores for technical execution ($p < 0.05$).

The coefficient of determination (r^2) has the value 0.53, which shows that the relationship between the final results for Shoulder extension and the final results for technical execution is strong.

- There is a significant positive correlation (0.945) between the final scores for Leg raises and the final scores for technical execution ($p < 0.01$).

The coefficient of determination (r^2) has the value 0.89, meaning that the association between the final scores for Leg raises and the final scores for technical execution is very strong.

- There is a statistically significant positive correlation (0.898) between the final results for Upper body extension and the final results for technical execution ($p < 0.05$).

The coefficient of determination (r^2) has the value 0.80, which shows that the relationship between the final results for Upper body extension and the final results for technical execution is very strong.

- There is a significant positive correlation (0.963) between the final scores for Leg extension and the final scores for technical execution ($p < 0.01$).

The coefficient of determination (r^2) has the value 0.92, which indicates that the relationship between the final scores for Leg extension and the final scores for technical execution is very strong.

- There is a significant positive correlation (0.952) between the final results for Handstand hold and the final results for technical execution ($p < 0.01$).

The coefficient of determination (r^2) has the value 0.90, meaning that the association between the final results for Handstand hold and the final results for technical execution is very strong.

- No correlations are found between the final results for Deep squats L, Upper body lifts, Standing long jump, Sargent test, 25 m sprint and the final results for technical execution ($p > 0.05$).

Discussion and Conclusion

In the literature, special attention is paid to the role of "coordination at landings performed in Women's Artistic Gymnastics" (Grigore et al., 2016, p. 423). According to Teodorescu et al. (2013), there is a strong correlation between "the resistance to mental fatigue and the performance of junior gymnasts" (p. 71). Romanian researchers (Popescu et al., 2015) have also investigated cerebral dominance in elite female artistic gymnasts in order to improve their future sports performance.

The effectiveness of combining maximum strength development training with plyometric training to increase vault efficiency in artistic gymnastics is also highlighted by other authors (Bogdanis et al., 2019; Ramirez-Campilio et al., 2013; Sáez-Saez de Villarreal et al., 2009).

Following the statistical analysis and interpretation of the research data, we can conclude that there are significant improvements in the scores obtained for physical tests (Deep squats R, Deep squats L, Arm lifts, Shoulder extension, Upper body lifts, Leg raises, Upper body extension, Leg extension, Handstand hold, Standing long jump, Sargent test, 25 m sprint) and for the technical execution test after the experimental intervention.

The present study also highlights that there is a significant positive correlation between the results obtained for technical execution and the results for Deep squats R, Arm lifts, Shoulder extension, Leg raises, Upper body extension, Leg extension and Handstand hold.

Taking into account the test results and their statistical interpretation, we recommend using the proposed physical training programme for the development of lower limb strength and the abdominal physical training programme for the improvement of Tsukahara vault in particular, as well as other technical elements based on take-off and jumps in general.

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