Discobolul – *Physical Education, Sport and Kinetotherapy Journal*, Volume 60, Issue 3, 265-279

THE DURATION OF TECHNICAL ELEMENTS IN RHYTHMIC GYMNASTICS JUMPS – A LONGITUDINAL AND CORRELATIONAL STUDY

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https://doi.org/10.35189/dpeskj.2021.60.3.6

Abstract. *The research purpose is to identify the development level of some skills/components that condition the execution of Body Difficulties in the group of Jumps/Leaps according to the requirements of the FIG Code of Points and increase the value of technical elements in competition routines. The research was conducted on 14 rhythmic gymnasts, members of the National Junior Team of Romania, and included two stages as follows: the first test took place in December 2019, and the second, in August 2020. Motor and biomechanical information was collected to objectify some motor skills involved in the performance of technical elements specific to the group of Jumps/Leaps. Muscle power, contact times, jump height, flight times and jump rhythm were assessed using the Microgate OptoJump Next device, and the duration of technical elements in the group of Jumps/Leaps was measured by a stopwatch. A programme for the improvement and consolidation of technical elements belonging to this group was applied during the research. Statistical analysis of the collected data required checking the normal distribution of results (using the Skewness and Kurtosis coefficients), identifying the mean differences between the two tests by applying the Student's t-Test and identifying correlations between the parameters resulting from the two tests using Pearson's correlation coefficients. Analysing the correlations between the investigated variables for both lower limbs, it can be stated that there is clear evidence of the dependency links between the two symmetrical segments as well as positive and negative correlations between OptoJump variables and the average duration of jumps.*

Keywords: *rhythmic gymnastics, jumps/leaps, OptoJump, Code of Points, duration, technical optimisation.*

Introduction

Rhythmic gymnastics has turned from a sport that was originally based on body expression and rhythmicity into a top-level Olympic sport with its specific motor content involving "a high degree of technicality, complexity, dynamism, expressiveness, spectacularity and elegance" (Manos & Popescu, 2020, p. 507).

Rhythmic gymnastics uses classical dance movements such as the position of upper and lower of limbs, elements of static and dynamic balance, elements with rotation, turns, elements that help change the direction of travelling, pivots and rotations, technical elements with values quantified by the FIG Code of Points, jumps and leaps (Putra et al., 2020). Jumps are elements that involve pushing oneself off the ground and moving one's body vertically by propelling it into the air (Macovei, 1999). A 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, which is associated with higher technical levels (Hashimoto et al., 2017).

Technical elements in the group of Jumps/Leaps are motor actions with a high degree of dynamism and proficiency, which show variety in terms of momentum and landing and can be performed with double foot take-off and landing on both feet, one foot take-off and landing on the same foot, one foot take-off and landing on the other foot (e.g., split leap/ jump), and double foot take-off and landing on one foot (e.g., stag leap/jump).

In addition to the first phases specific to artistic jumps, namely run-up and take-off, there is also a third phase, flight, which consists in propelling one's body vertically and describing a well-defined shape that allows to identify the type of element intended to be performed. According to Hutchinson et al. (1998), a high level of technical training is needed to be able to achieve the shape during the flight in optimal conditions. Cicchella (2009) believes that a good understanding and structuring of sports training requires conducting a descriptive kinematic analysis of the technical elements specific to rhythmic gymnastics, which can help identify the faults made by athletes while performing them. If the two aforementioned authors think that good technical support is needed to perform jumping elements, Piazza et al. (2014) consider that the ability to perform jumps in an optimal way requires the implementation of resistance training programmes along with traditional dynamic strength conditioning.

According to the FIG Code of Points (FIG, 2018), jumps and leaps must have a well-defined shape, and their height must be sufficient to allow the gymnast to show the corresponding shape. The flight phase depends on the quality of the take-off, and its duration is influenced by muscle power and jump height (Santos et al., 2016). Argumentative studies (Piazza et al., 2014; Douda et al., 2008) determined the ratio of some of these components in the final score - explosive power (9.2%) and anthropometric measurements (45%), the latter being decisive for all physical abilities.

Research objectives

Identifying the development level of some skills/components that condition the technical execution of Body Difficulties in the group of Jumps/Leaps according to the requirements of the FIG Code of Points.

Identifying correlations between the duration of jumps performed by the experimental group in competition routines and the parameters assessed using the OptoJump Next device, namely: muscle power, contact times, jump height, flight times and jump rhythm.

Research hypothesis

Using the OptoJump equipment exclusively as a tool to assess motor skills in non-specific conditions for rhythmic gymnastics does not always create the premises to identify correlations between its parameters and the variables specific to the Difficulty elements in the group of Jumps/Leaps.

Methodology

Participants

The research was conducted on junior gymnasts belonging to CS UNEFS Bucharest, CSM Arad and CSM Ploiești clubs, members of the National Individual and Group Team. They started centralised training sessions in November 2018 at the National Olympic Junior Training Centre in Arad, under the coordination of coach Daniela Chiriac.

The 14 gymnasts included in the research are aged 13-15 and have between 7 and 10 years of experience in rhythmic gymnastics.

The gymnasts' level of technical preparation is heterogeneous, which is due to the different ways of addressing training in their clubs of origin and obviously to their different somatic, motor and psychological characteristics.

Procedure

Participants were first tested in December 2019 at the "Alexandru Partheniu" Interdisciplinary Research Centre in UNEFS Bucharest, and the second test was performed in August 2020, during the Covid-19 pandemic. Between March and mid-May, the investigated gymnasts followed home training sessions due to global confinement. The coach tried to reduce their physical and technical de-training by scheduling 4 hours of training lessons per day; however, the girls were affected by this unprecedented event in terms of weight gain, decreased endurance and lower levels of overall fitness. These drawbacks were reported by many studies addressing the impact of Covid-19 on athletes' performance capacity (Eirale et al., 2020). One of the challenges revealed by coaches during the pandemic was the difficulty to monitor training loads, especially exercise intensity and complexity (Jukic et al., 2020).

In this study, the duration of jumps performed during the ball, clubs and ribbon exercises was measured. The assessments took place twice, in December 2019 and August 2020. Each gymnast had to perform three repetitions for each element specific to the group of Jumps/ Leaps during their competition routines. Execution times were measured using a stopwatch, and the three values were recorded and statistically processed. The average execution time was calculated for all elements that were correctly performed in technical terms.

Research methods

The study of the literature included recent scientific articles regarding trends in the current FIG Code of Points, as well as issues related to the specific rhythmic gymnastics training and the scientific research methodology.

During the implementation of the technical training programme, pedagogical observation was used to notice the gymnasts' physical and mental reactions to it but also their performance throughout the experiment.

Given that an experiment identifies the relationship between two phenomena, the independent variable of this study was the content of the technical training programme, and its dependent variable, the investigated parameters susceptible to progress.

The administration of the independent variable included exercises to improve the technical execution of Body Difficulties, exercises specific to classical ballet, exercises to reduce execution times and exercises to develop lower body strength within a macrocycle.

In this study, the measurement consisted in collecting motor and biomechanical information to objectify some motor skills involved in performing the specific elements of technical training for the group of Jumps/Leaps.

Tests used in the research

The following tests were used to assess motor skills: muscle power, contact times, flight times, jump height and jump rhythm, which were measured with the Microgate OptoJump Next device. Its two-dimensional configuration (Figure 1) facilitates the execution of in-place straight jumps, in-place single-leg jumps and single-leg jumps with travelling on the x- and y-axes. Due to the collection of these data and the possibility to make a video analysis of the athlete's performance, the operator/coach can quickly assess explosive power, the time of fatigue onset, the position of the body during the jump and the execution technique.

For a more refined investigation, the two-dimensional version of this device allows using four bars, two on the x-axis and two on the y-axis, which form a measuring area between 1 x 1 and 6 x 6 m (Figure 2). The signal transmission-reception distance is up to 6 m; with this equipment, the athlete can use maximum 5 m in the direction of x-bars and 50 cm in the direction of y-bars when performing a jumping element.

Figure 1. OptoJump equipment configuration - Two-dimensional version

Figure 2. Gymnast using OptoJump

The device also allows real-time display on the monitor of the athlete's movement within the created perimeter. For example, during a test that involves performing in-place straight jumps for 15 seconds, the operator/coach can visualise how far the athlete has moved from the initial point and thus the subject's level of neuromuscular control in this task.

Figure 3 shows an example of compliance with the task, where the athlete kept the initial point (marked in pink) within reasonable limits, and an example in which the athlete moved uncontrollably over an extended perimeter.

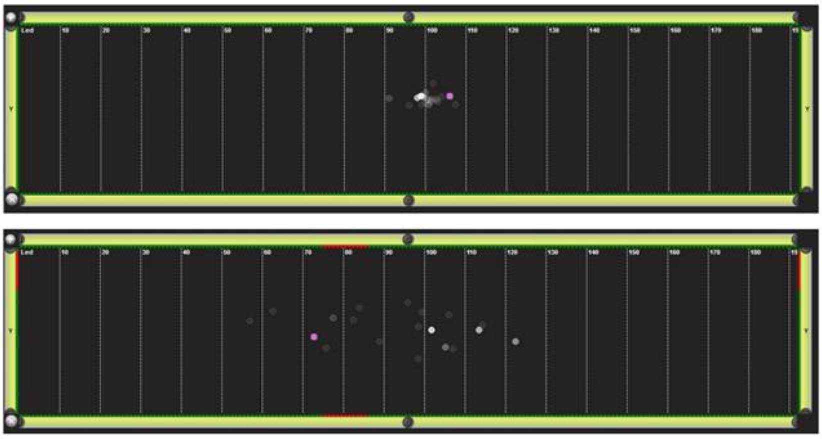

Figure 3. Representation of the athlete's displacement from the initial point as provided by the OptoJump software – Examples

The significance of this test is given by both the athlete's level of muscle power and ability to focus in order to achieve the established task. In rhythmic gymnastics, power is meaningless in the absence of neuromuscular control.

Research participants performed the following tests:

- In-place straight jumps on the right leg, 5 repetitions;
- In-place straight jumps on the left leg, 5 repetitions;
- Straight jumps on the right leg with forward-backward movements, 5 repetitions;
- Straight jumps on the left leg with forward-backward movements, 5 repetitions.

In this study, the mathematical and statistical method was used after recording the data resulting from the tests performed by the investigated athletes. Thus, the differences in technical training within the group of subjects were identified and checked by analysing the variables obtained from measurements, comparing their mean values, making correlations and observing the values of the coefficient of variation for each parameter concerned.

In order to verify the normal distribution of athletes' results, the Skewness and Kurtosis coefficients were used. The absolute Skewness coefficient was less than 1, the Kurtosis coefficient did not exceed 8, and the Skewness coefficient did not exceed 3 (Kline, 2013).

To statistically validate the research hypothesis, the Paired Samples t-Test was used.

To analyse the degree of association between the assessed variables/parameters, Pearson's correlation was used for a sample of no more than 30 subjects. A significance threshold of $p < 0.05$ was taken into account to argue significant correlations.

For the interpretation of Pearson's correlation coefficients, the following values were considered:

- $r = 0 \rightarrow$ lack of correlation;
- $r = 1 \rightarrow$ perfect positive correlation;
- $r = -1 \rightarrow$ perfect negative correlation;
- $r = 0.2$ (-0.2) $\rightarrow$ weak positive or negative correlation;
- $r = 0.5$ (-0.5) $\rightarrow$ moderate positive or negative correlation;
- $r = 0.8$ (-0.8) $\rightarrow$ strong positive or negative correlation.

For the statistical interpretation, the r-effect size was used to identify the strength of association and thus the extent to which the independent variable affected the dependent variable.

For data processing, the Microsoft Excel product was used to compute the total, mean value (M), standard deviation (SD) and coefficient of variation, along with the Statistical Package for the Social Sciences (SPSS).

Results

Processing and interpretation of biomechanical parameters involved in performing elements specific to the group of Jumps/Leaps

Analysis of the results obtained by assessing Body Difficulties specific to the group of Jumps/Leaps was complemented by the interpretation of dynamic and kinematic parameters considered to be decisive for the execution of elements included in this group: muscle power, ground contact times, jump height and flight times.

Table 1 shows the descriptive statistics for both the aforementioned variables and each symmetrical segment, namely the left and right lower limbs.

Although the investigated sample is small, all the analysed variables are normally distributed. The absolute Skewness coefficient is less than 1 or the values of symmetry (Skewness) and flatness (Kurtosis) indicators are within the limits considered to be normal (they do not exceed the value 3 for Skewness and the value 8 for Kurtosis).

Table 1. *Descriptive statistics for the test variables analysed in the straight jumps on one leg (left and right)*

Descriptive Statistics									
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
LEFT test 1 right contact T	14	.3	.6	.37	.080	1.23	.597	1.322	1.15
LEFT test 1 right flight T	14	.2	.3	.29	.036	-.95	.597	.961	1.15
LEFT test 1 right height	14	5.4	14.6	10.55	24.32	-.62	.597	.437	1.15
LEFT test 1 right power	14	7.4	18.4	13.12	30.47	-.21	.597	-.267	1.15
LEFT test 1 right rhythm	14	1.3	1.7	1.51	.122	-.91	.597	.179	1.15
LEFT test 2 right contact T	14	.3	.5	.36	.049	.83	.597	.251	1.15
LEFT test 2 right flight T	14	.3	.4	.30	.035	.30	.597	-1.520	1.15
LEFT test 2 right height	14	8.4	16.1	11.67	27.00	.39	.597	-1.438	1.15
LEFT test 2 right power	14	10.1	18.9	13.91	29.99	.40	.597	-1.380	1.154
LEFT test 2 right rhythm	14	1.3	1.6	1.48	.073	-.60	.597	1.122	1.15
RIGHT test 1 right contact T	14	.3	.5	.348	.057	1.48	.597	1.761	1.15

RIGHT test 1 right flight T	14	.2	.3	.280	.038	-.62	.597	-.871	1.15
RIGHT test 1 right height	14	5.5	13.3	9.87	25.62	-.486	.597	-.982	1.15
RIGHT test 1 right power	14	7.8	16.2	12.82	27.33	-.463	.597	-.919	1.15
RIGHT test 1 right rhythm	14	1.3	1.8	1.59	.139	-.137	.597	.123	1.15
RIGHT test 2 right contact T	14	.3	.5	.36	.056	.588	.597	-.701	1.15
RIGHT test 2 right flight T	14	.2	.4	.30	.036	-.568	.597	.303	1.15
RIGHT test 2 right height	14	6.8	16.3	11.42	26.44	-.173	.597	.026	1.15
RIGHT test 2 right power	14	8.4	20.6	13.86	31.51	.169	.597	.643	1.15
RIGHT test 2 right rhythm	14	1.3	1.7	1.50	.091	.081	.597	-.043	1.15
Valid N (listwise)	14								

Apart from the central tendency indicators, Student's t-Test was applied to identify the significance of mean differences between the two tests.

Table 2. *Results of the Paired Samples t-Test for the variables analysed in the straight jumps on the left leg*

		Paired Samples t-Test Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval for the Mean Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Left test 1 contact T Left test 2 contact T	.00607	.07109	.01900	-.03497	.04712	.320	13	.754
Pair 2	Left test 1 flight T Left test 2 flight T	-.01564	.04468	.01194	-.04144	.01016	-1.310	13	.213
Pair 3	Left test 1 height Left test 2 height	-112.143	324.705	.86781	-299.622	.75336	-1.292	13	.219
Pair 4	Left test 1 power Left test 2 power	-.79071	351.482	.93938	-282.011	123.869	-.842	13	.415
Pair 5	Left test 1 rhythm Left test 2 rhythm	.02857	.09960	.02662	-.02894	.08608	1.073	13	.303

The results of the Paired Samples t-Test for the two tests show that (Table 2):

- There are no statistically significant differences ($p < 0.05$) between the first test and the second test in the jumps on the left leg for any of the analysed variables.
- Although statistically insignificant, the values are lower in the second test than in the first test for contact time (M = 0.366, SD = 0.049 compared to M = 0.372, SD = 0.080) and rhythm (M = 1.487, SD = 0.073 compared to M = 1.516, SD = 0.122). The values are higher in the second test than in the first test for flight time (M = 0.306, SD = 0.035 compared to M = 0.290, SD = 0.036), jump height (M = 11.671, SD = 2.700 compared to M = 10.550, SD = 2.432) and power (M = 13.912, SD = 2.999 compared to M = 13.121, SD = 3.047).

Table 3. *Results of the Paired Samples t-Test for the variables analysed in the straight jumps on the right leg*

		Paired Samples t-Test							
		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval for the Mean Difference				
					Lower	Upper			
Pair 1	RIGHT test 1 contact T RIGHT test 2 contact T	-.0148	.0603	.0161	-.0496	.0200	-.918	13	.375
Pair 2	RIGHT test 1 flight T RIGHT test 2 flight T	-.0220	.0405	.0108	-.0454	.0014	-2.033	13	.063
Pair 3	RIGHT test 1 height RIGHT test 2 height	-15.429	26.972	.7209	-31.002	.0145	-2.140	13	.052
Pair 4	RIGHT test 1 power RIGHT test 2 power	-10.364	28.059	.7499	-26.565	.5836	-1.382	13	.190
Pair 5	RIGHT test 1 rhythm RIGHT test 2 rhythm	.0864	.1278	.0342	.0126	.1602	2.530	13	.025

The results of the Paired Samples t-Test for the two tests show that (Table 3):

- There is a statistically significant difference ($p < 0.05$) between the first test and the second test in the jumps on the right leg for rhythm, $t(13) = 2.53$, $p = 0.025$, with a higher effect value ($d = 0.73$). The value of this variable is lower in the second test than in the first test ($M = 1.506$, $SD = 0.091$ compared to $M = 1.592$, $SD = 0.139$);
- There are no statistically significant differences ($p < 0.05$) between the first test and the second test in the jumps on the right leg for contact time, flight time, jump height and power. The effect size is low for contact time ($d = 0.27$) and power ($d = 0.35$) and high for flight time ($d = 0.54$) and jump height ($d = 0.62$);
- The values are higher in the second test than in the first test for the following variables: contact time ($M = 0.362$, $SD = 0.056$ compared to $M = 0.347$, $SD = 0.057$), flight time ($M = 0.302$, $SD = 0.036$ compared to $M = 0.280$, $SD = 0.038$), jump height ($M = 11.421$, $SD = 2.644$ compared to $M = 9.878$, $SD = 2.562$) and power ($M = 13.861$, $SD = 3.151$ compared to $M = 12.825$, $SD = 2.733$).

Table 4 shows the descriptive statistics corresponding to the two tests for the jumps on one leg (left and right) with forward-backward movements.

Table 4. *Descriptive statistics for the test variables analysed in the jumps on one leg (left and right) with forward-backward movements*

Descriptive Statistics									
	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
LEFT test 1 forward-backward contact T	14	.3	1.0	.464	.1863	2.406	.597	6.579	1.15
LEFT test 1 forward-backward flight T	14	.2	.3	.262	.0356	-.428	.597	-.080	1.15
LEFT test 1 forward-backward height	14	4.2	11.6	8.586	22.487	-.144	.597	-.725	1.15
LEFT test 1 forward-backward power	14	6.0	14.4	10.715	25.330	-.165	.597	-.819	1.15
LEFT test 1 forward-backward rhythm	14	1.1	1.7	1.475	.1637	-.888	.597	-.041	1.15
LEFT test 2 forward-backward contact T	14	.3	.5	.418	.0637	.671	.597	-.726	1.15
LEFT test 2 forward-backward flight T	14	.2	.3	.268	.0348	.539	.597	-.832	1.15
LEFT test 2 forward-backward height	14	6.0	13.3	8.971	23.614	.650	.597	-.750	1.15
LEFT test 2 forward-backward power	14	7.8	15.1	10.897	25.180	.463	.597	-1.133	1.15
LEFT test 2 forward-backward rhythm	14	1.3	1.7	1.478	.1048	.025	.597	.214	1.15
RIGHT test 1 forward-backward contact T	14	.3	.6	.400	.0836	1.696	.597	3.446	1.15
RIGHT test 1 forward-backward flight T	14	.2	.3	.261	.0427	-.973	.597	1.753	1.15
RIGHT test 1 forward-backward height	14	2.5	13.1	8.564	26.814	-.616	.597	1.325	1.15
RIGHT test 1 forward-backward power	14	5.2	15.0	10.996	27.615	-.578	.597	.254	1.15
RIGHT test 1 forward-backward rhythm	14	1.1	2.8	1.624	.3823	2.631	.597	9.081	1.15
RIGHT test 2 forward-backward contact T	14	.3	.6	.401	.0785	1.644	.597	4.184	1.15
RIGHT test 2 forward-backward flight T	14	.2	.3	.272	.0354	.002	.597	-.722	1.15
RIGHT test 2 forward-backward height	14	6.1	13.3	9.271	23.385	.293	.597	-.623	1.15
RIGHT test 2 forward-backward power	14	6.5	16.6	11.454	28.013	.200	.597	-.294	1.15
RIGHT test 2 forward-backward rhythm	14	1.2	1.7	1.510	.1204	-.339	.597	.864	1.15
Valid N (listwise)	14								

Besides the central tendency indicators, Student's t-Test was applied to identify the significance of mean differences between the two tests.

Table 5. *Results of the Paired Samples t-Test for the variables analysed in the jumps on the left leg with forward-backward movements*

		Paired Samples t-Test Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval for the Mean Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	LEFT test 1 forward-backward contact T LEFT test 2 forward-backward contact T	.0457	.1662	.0444	-.0503	.1417	1.029	13	.322
Pair 2	LEFT test 1 forward-backward T flight T LEFT test 2 forward-backward flight T	-.0066	.0357	.0095	-.0272	.0140	-.689	13	.503
Pair 3	LEFT test 1 forward-backward height LEFT test 2 forward-backward height	-.3857	23.191	.6198	-17.247	.9533	-.622	13	.544
Pair 4	LEFT test 1 forward-backward power LEFT test 2 forward-backward power	-.1821	26.612	.7112	-17.187	13.544	-.256	13	.802
Pair 5	LEFT test 1 forward-backward rhythm LEFT test 2 forward-backward rhythm	-.0029	.1272	.0340	-.0763	.0706	-.084	13	.934

The results of the Paired Samples t-Test for the two tests show that (Table 5):

- There are no statistically significant differences ($p < 0.05$) between the first test and the second test in the jumps on the left leg with forward-backward movements for any of the analysed variables.
- Although statistically insignificant, the value is lower in the second test than in the first test for contact time (M = 0.417, SD = 0.063 compared to M = 0.463, SD = 0.186). The values are higher in the second test than in the first test for the following variables: flight time (M = 0.268, SD = 0.034 compared to M = 0.261, SD = 0.035), jump height (M = 8.91, SD = 2.361 compared to M = 8.585, SD = 2.248), power (M = 10.897, SD = 2.517 compared to M = 10.715, SD = 2.533) and rhythm (M = 1.477, SD = 0.104 compared to M = 1.475, SD = 0.163).

Table 6. *Results of the Paired Samples t-Test for the variables analysed in the jumps on the right leg with forward-backward movements*

Paired Samples t-Test

		Paired Differences					T	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval for the Mean Difference				
					Lower	Upper			
Pair 1	RIGHT test 1 forward-backward contact T RIGHT test 2 forward-backward contact T	-.0009	.0480	.0128	-.0286	.0268	-.072	13	.943
Pair 2	RIGHT test 1 forward-backward flight T RIGHT test 2 forward-backward flight T	-.0116	.0396	.0106	-.0344	.0113	-1.093	13	.294
Pair 3	RIGHT test 1 forward-backward height RIGHT test 2 forward-backward height	-.7071	23.669	.6326	-20.738	.6595	-1.118	13	.284
Pair 4	RIGHT test 1 forward-backward power RIGHT test 2 forward-backward power	-.4579	26.818	.7167	-20.063	10.906	-.639	13	.534
Pair 5	RIGHT test 1 forward-backward rhythm RIGHT test 2 forward-backward rhythm	.1143	.3508	.0938	-.0883	.3169	1.219	13	.245

The results of the Paired Samples t-Test for the two tests show that (Table 6):

- There are no statistically significant differences ($p < 0.05$) between the first test and the second test in the jumps on the right leg with forward-backward movements for any of the analysed variables.
- Although statistically insignificant, the value is lower in the second test than in the first test for rhythm (M = 1.51, SD = 0.12 compared to M = 1.62, SD = 0.38). The values are higher in the second test than in the first test for the following variables: contact time (M = 0.400, SD = 0.078 compared to M = 0.399, SD = 0.083), flight time (M = 0.272, SD = 0.035 compared to M = 0.260, SD = 0.042), jump height (M = 9.271, SD = 2.338 compared to M = 8.564, SD = 2.681) and power (M = 11.453, SD = 2.801 compared to M = 10.995, SD = 2.761).

Similar research on the explosive power of lower limbs was developed by Santos et al. (2016), with the difference that they assessed jumps specific to rhythmic gymnastics. Either way, studies have revealed that strength and power impact the majority of technical elements, therefore physical abilities should complement flexibility workouts in all training periods.

For illustrative purposes, we present below two graphs (Figure 4 and Figure 5) showing one of the tests performed with the OptoJump equipment by the gymnast B.I., which highlight the deviation of ground contact points from the initial point for each jump. These representations provide information about the athlete's ability to perform successive jumps with high neuromuscular control even after the onset of fatigue.

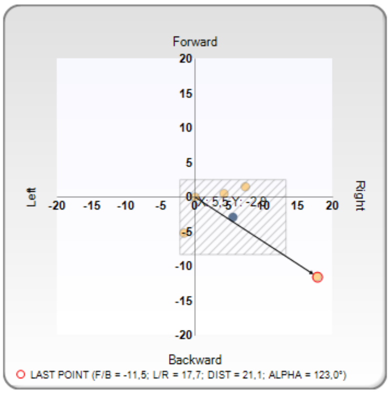

Figure 4. Simple jumps on the right leg - B.I.

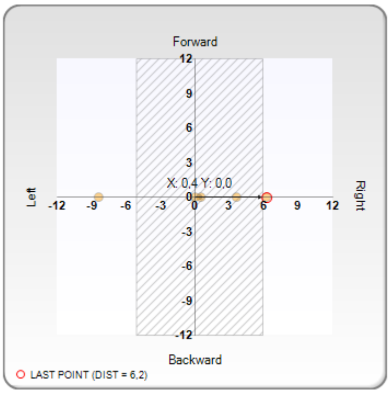

Figure 5. Simple jumps on the left leg - B.I.

Table 7 shows the average results for the duration of jumps and the difference between its initial mean and final mean. It is noted that the average duration for execution has decreased by 0.29 seconds in the second test compared to the first test, and this value is statistically significant at a threshold lower than 0.001.

Table 7. *Paired Samples t-Test for the duration of jumps*

Means		
	Initial test	*Final test*
Mean	2.693461	2.403457054
Variation	0.067567	0.07016766
Observations	14	14
Pearson's Correlation	0.554251	
Hypothesised Mean Difference	0	
Df	13	
t Stat	4.378778	
P(T <= t) one-tail	0.000373	
t Critical one-tail	1.770933	
P(T <= t) two-tail	0.000746	
t Critical two-tail	2.160369	

Correlative interpretation of the variables investigated through specific and non-specific tests

From the multitude of data collected for the variables corresponding to the level of technical training and the components assessed in laboratory conditions through non-specific tests, the largest number of correlations were identified between the variables analysed using the OptoJump device.

In terms of correlations between the OptoJump variables and the average duration of Jumps/Leaps as Body Difficulty elements, only one correlation with the rhythm variable for single-leg jumps with forward-backward movements (r = 0.555*) was highlighted in the first test, while in the second test, a negative correlation (r = -542*) was identified with contact times for single-leg jumps with forward-backward movements and a positive correlation with the rhythm variable (r = 0.634*) for single-leg vertical jumps and single-leg jumps with forward-backward movements (r = 0.635*).

The above-mentioned negative correlation demonstrates that ground contact time varies inversely proportionally (up to a limit) with the time needed to show the corresponding shape of the jump. In other words, if ground contact time is longer, the stretching-shortening cycle of the muscles involved in that action loses part of the "speed component" necessary to produce an active momentum, and the duration of the jump will be shorter. Of the multiple significant correlations at $p < 0.01$, we mention only a few, which are relevant for arguing the technical training of Body Difficulties.

In the first test for single-leg vertical jumps:

- for the left lower limb, strong correlations were highlighted between flight time, jump height (r = 0.997) and muscle power (r = 0.936);
- for the right lower limb, strong correlations were highlighted between flight time and jump height (r = 999) and muscle power (r = 0.924).

In the second test for single-leg vertical jumps:

- for the left lower limb, strong correlations were revealed between flight time, jump height (r = 0.999) and muscle power (r = 0.973);
- for the right lower limb, strong correlations were revealed between flight time and jump height (r = 995) and muscle power (r = 0.953).

In the first test for single-leg jumps with forward-backward movements:

- for the left lower limb, strong correlations were identified between flight time, jump height (r = 0.997) and muscle power (r = 0.945);
- for the right lower limb, strong correlations were identified between flight time and jump height (r = 997) and muscle power (r = 0.935).

In the second test for single-leg jumps with forward-backward movements:

- for the left lower limb, strong correlations were found between flight time, jump height (r = 0.999) and muscle power (r = 0.978);
- for the right lower limb, strong correlations were found between flight time and jump height (r = 994) and muscle power (r = 0.937).

Analysing the correlations between the investigated variables for both lower limbs, it can be stated that there is clear evidence of the dependency links between the two symmetrical segments. Thus, there are strong correlations between contact time, flight time, jump height, muscle power and rhythm for the left and right lower limbs, which is explained by the coaches' concern to address physical training in a balanced way for all body segments regardless of their contribution to the execution of the specific technique.

The analysis of statistical correlations between the variables assessed using the OptoJump device and the variables specific to technical Difficulties in the group of Jumps/Leaps shows that the research hypothesis has been partially accepted, given that the average duration of jumps in the composition of rhythmic gymnastics routines is correlated only with contact times and the rhythm of jumps performed in laboratory conditions.

Conclusion

The investigation of muscle power, contact time, flight time and height time parameters highlighted statistically insignificant progress for both the two tests and the two symmetrical segments, namely the left and right lower limbs. However, the collected data were relevant for the physical training of each rhythmic gymnast.

Data regarding the deviations of ground contact points from the initial point during successive vertical jumps provide coaches with information about each gymnast's neuromuscular control ability, balance and level of specific endurance. Also, each gymnast's pattern of deviations can be identified depending on the support leg and the onset of fatigue.

The average duration of jumps for the group of gymnasts decreased significantly due to a complex exercise programme aimed to improve the technique while increasing the speed of execution.

Using the OptoJump equipment exclusively as a tool to assess motor skills in non-specific conditions for rhythmic gymnastics does not always create the premises to identify correlations between its parameters and the variables specific to the Difficulty elements in the group of Jumps/Leaps.

Acknowledgements

We thank the team of the "Alexandru Partheniu" Interdisciplinary Research Centre in UNEFS Bucharest, who provided us with the equipment and logistics necessary for biomechanical investigations.

Our thanks to the technicians of the National Olympic Junior Training Centre in Arad for giving us the opportunity to intervene in the athletic training process, showing total openness and support.

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