

Preliminary Study on Psychomotor Abilities Decisive for Technical Routines in Rhythmic Gymnastics

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Abstract: *The aim of the research is to establish the level of some psychomotor abilities by determining the rhythmic gymnasts' capability to perform apparatus-specific technical skills within the composition of their routines, according to the provisions of the 2017-2020 Code of Points. The Wireless training timer (Witty) testing equipment was used to assess relevant types of speed in junior rhythmic gymnasts. The reaction time, execution time and travel speed time were measured in similar technical conditions or close to those encountered in training and competitions. The 14 gymnasts included in the research, aged between 13 and 15 years, are part of the National Olympic Centre for juniors in Arad, all being enrolled in the preparatory stage of training. The analysis of the data from both static and dynamic tests established a referential for the forms of speed to be enhanced by means of apparatus-specific technical routines. Results provide interesting information on the average values, inter-individual differences and homogeneity-related issues (which are relevant especially for gymnasts performing in the group event). The key features of these data, as well as previous analysis of junior routines for the 2017-2020 Olympic cycle, have led us to the conclusion that, in order to get a high score for apparatus difficulty/mastery, more difficulty elements should be added, which requires an increase in all kinds of speed involved by the technique of a specific event.*

Keywords: *rhythmic gymnastics; Code of Points; difficulty elements; Witty test.*

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Introduction

Rhythmic gymnastics is an Olympic female sport in which athletes perform to music using different hand apparatus and following a pre-determined composition of exercises (Hashimoto, Kida, & Nomura, 2017). Considering that sport competitions with choreography or routines require a combination of movement and music, they both play a major role in this regard, together with overall visual and audio aspects (Chiat & Ying, 2012, p. 1207).

In the current context of high-performance sport and sport show, rhythmic gymnastics is going through a difficult transition period, facing major changes over the last decade, which have been transposed into the rules imposed at each new edition of the FIG Code of Points (2018). This document developed by the Technical Committee of the International Gymnastics Federation undergoes changes every four years but can be updated anytime during an Olympic cycle (Trifunov & Dobrijevic, 2013, p. 120) in order to increase the objectivity of the judges' scoring and stimulate the development of this sport discipline (Sierra-Palmeiro et al., 2019). According to the study conducted by Leandro et al. (2017) on the issue of judging in rhythmic gymnastics at different levels of performance, there are problems judging medium-level athletes (in the second part of the ranking) mainly due to the lack of clearness and precision of the 2013-2016 Code of Points. As a result, major changes have been made to the new edition of the regulation in 2017 as regards the judging criteria.

In an attempt to turn gymnastics competitions into events as attractive as possible for the general public, the International Gymnastics Federation seeks to regulate these issues using an instrument specific to all branches of Olympic gymnastics, namely the difficulty criterion. At the end of 2017, the technical committees decided to remove the maximum limit for this criterion, a change made after the first competitive year of this Olympic cycle, which has led to substantial modifications in the related scores and therefore in the final score.

This is illustrated in Figure 1 that shows the final scores obtained by the world champion in the last three editions of the Senior World Championships for the individual all-around event. To note that the final score results from totalling the scores of each individual exercise performed with the following apparatus: hoop, ball, clubs and ribbon.

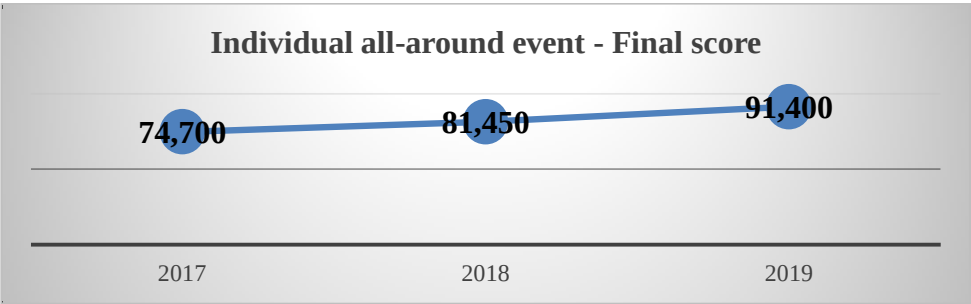


Figure 1. All-around final scores of the world champion, senior category, from 2017 to 2019

Source: authors'own contribution

Opening the difficulty score in rhythmic gymnastics compels coaches to look for (solutions to increase the overall value of the routine and to focus on this judging criterion. Leandro et al. (2016) believe that coaches need to analyse the success probability of the elements introduced in competition compositions and to optimise the training process for those groups of elements so as to ensure the athlete's success in competition, while being careful to maintain good variation in the choice of elements.

Difficulty is divided into two components, one comprising the body technique elements (a sub-criterion named BD – Body Difficulty), and the other containing elements related to the apparatus handling technique (a sub-criterion named AD – Apparatus Difficulty) (Figure 2).

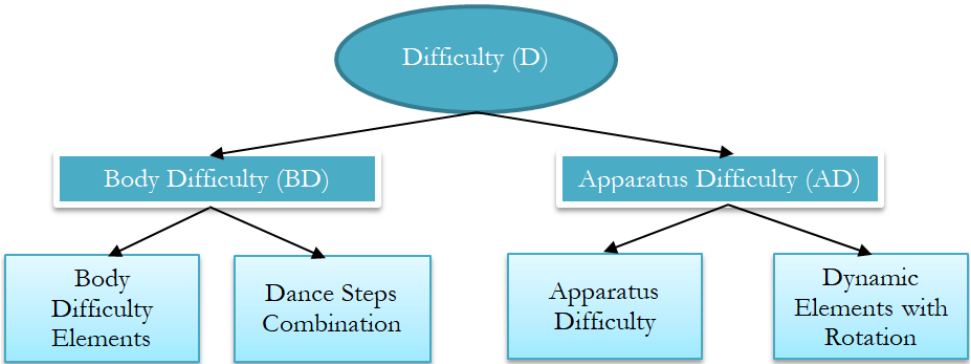


Figure 2. Components of the difficulty criterion

Source: authors'own contribution according to FIG Code of Points

The FIG requirements for Difficulty are as follows (FIG, 2018): minimum 3 and maximum 7 body difficulty elements for junior gymnasts and maximum 9 for senior gymnasts, while Dance Steps Combinations do not have an upper limit (minimum 1 – unlimited) but must last minimum 8 seconds each. Technical difficulty elements are divided into dynamic elements with rotation (maximum 4 for juniors and 5 for seniors) and apparatus difficulty.

According to Agopyan (2014), the effects of changes in the FIG Code of Points can be identified by analysing the competition routines of elite gymnasts, even if very few studies have been conducted in this regard. This is also highlighted by Ávila-Carvalho et al. (2012), who have found that there are studies on the value of technical elements, but not on their number in competition compositions.

Analysing the routines of finalist gymnasts at the 2018 European Junior Championships held in Guadalajara (Spain) in the all-around event, we have found that leading gymnasts succeed to perform a higher number of apparatus difficulty elements, a maximum number of dynamic elements with rotations and body difficulty elements in the Rotations group with increased values. This approach to compositions and technical training gives gymnasts a better chance of success in competition.

The study mentioned above (Agopyan, 2014) and the research by Agopyan and Serdil Ors (2019) on the routines performed at the Rio 2016 Olympics highlight that gymnasts chose the same body difficulty elements for all 4 compositions, which has led to the lack of variation in body difficulty.

The study conducted by Leandro et al. (2017) reveals that judges also report an obvious lack of variation in difficulty elements for apparatus handling and want FIG to introduce rules that restrict the repetitive use of the same elements.

In order to achieve future sport performance, the current requirements of the Code of Points and its trends must be taken into account so as to provide good motor support and an optimum level of coordination abilities specific to rhythmic gymnastics, thus creating the prerequisites that will allow gymnasts to learn a large number of technical elements both in terms of body movement and apparatus handling (Moskovljević et al., 2013).

Purenovic-Ivanovic et al. (2016) consider that rhythmic gymnastics is a complex sport that requires increased spatial-temporal coordination between body movement and apparatus handling, thus making specific coordination a vital part of training in rhythmic gymnastics.

According to Miletić, Katić and Malesš (2004), coordination is the athlete's ability to perform complex movements, concomitantly solve motor tasks in different planes and axes, show optimum adaptability to new and difficult elements, which is one of the determining factors of motor proficiency and sport success.

The increased pace of development of rhythmic gymnastics has directly led to a continuous increase in technical abilities, which is why specific motor skills require a remarkable development of coordination ability (ability to direct and control movement, kinaesthetic differentiation ability, ability to control apparatus handling, anticipation ability, distance estimation ability, spatial-temporal orientation ability, rhythm, ability to control static and dynamic balance) (Manos, 2008).

According to Jastrjembskaia and Titov (1999, p. 137), specific coordination is a primordial element in rhythmic gymnastics training because it represents the gymnast's support for learning various technical elements.

Given that the most important objective of the training is to increase the number of technical difficulty elements in competition compositions, in addition to increasing the level of coordination abilities, we must also consider some conditional abilities that underpin the high-level performance of the competition routine.

Speed plays an important role because there is a directly proportional relationship between the increase in speed and the increased value of the composition. In rhythmic gymnastics, the main characteristic of speed is the fast execution of body movements and apparatus handling in a perfectly coordinated manner.

In rhythmic gymnastics, the forms of manifestation of speed are simple and complex reaction speed and execution speed, which are conditioned by the levels of body technique, ability and precision in the fast apparatus handling, as well as by optimal rapid strength in relation to external resistance and the level of specific coordination ability (Manos, 2008, pp. 33-34).

Given these features, it can be assumed that the psychological pressure that the gymnast feels due to the increased number of difficulty elements is considerable. In these conditions, there are two important issues that are possible to increase the stress level of gymnasts. The first one refers to the fact that most difficulty elements, both the apparatus difficulty and dynamic elements with rotation, are considered as risk elements for the loss of the apparatus. The second aspect is the "agglomerated" composition, with effects on the higher level of concentration.

In rhythmic gymnastics, competition compositions are created in such a way that they provide continuity, avoiding the moments of interruption. Each difficulty element is logically and fluidly connected to the others through transition movements and elements, and the failure of one of them leads to the invalidation of a considerable part of the exercise. Exercise fluidity is analysed in light of the artistic component objectified by dynamic changes, the relation of movements with music, the use of space, expression and variation (Kritikou et al., 2017).

Through the tests used to carry out the experiment, we aim to identify some aspects of coordination ability, as well as some characteristics of reaction speed, execution speed and travel speed, in conditions purposely designed to meet the apparatus difficulty sub-criterion, namely the apparatus handling technique.

The proposal of the International Gymnastics Federation for the next Olympic cycle is to create balance between the specific components of rhythmic gymnastics, namely body difficulty, apparatus difficulty, artistry and execution (precision) so as compositions can provide gymnasts with the opportunity to express the idea of the exercise as correctly as possible in technical terms and at a high level of difficulty. In parallel, coaches will constantly search for solutions to reach the highest possible scores with their gymnasts.

Currently, the Code of Points allows gymnasts to perform an unlimited number of apparatus difficulty elements, which creates an imbalance between difficulty and execution, thus affecting in particular the artistic sub-criterion.

Research questions

Will the improvement of execution speed, reaction speed and travel speed lead to an increased score for the Difficulty component?

Will the identification of the levels of reaction speed and execution speed for each athlete help the coach to create optimum combinations of apparatus difficulty elements that can be introduced in competition compositions?

Purpose of the study

This study aims to identify the levels of reaction speed, execution speed and travel speed, which will help gymnasts to perform apparatus difficulty elements as fast as possible, thus providing them with the opportunity to introduce a higher number of elements in competition

compositions. The final goal is to increase the overall score for the Difficulty criterion.

Methodology

Measurement and assessment methods

In this study, the measurement consisted in collecting motor and biomechanical information necessary to objectify some motor skills involved in the execution of apparatus difficulty elements.

Tests used in the research – Assessment of (psycho)motor skills

The following tests and equipment were used to assess motor skills:

a) Reaction speed, execution speed, travel speed. These forms of manifestation of speed were tested using the Wireless training timer (Witty) equipment that allowed the measurement of reaction speed and execution speed in a static position, as well as the measurement of travel speed in combination with the other forms, in a dynamic action.

For test 1 (Figure 3), the chosen position was Standing on tiptoes because most rhythmic gymnastics exercises are performed in demi-pointe. Athletes had the task to turn off 20 light signals that were displayed as soon as the gymnast has turned off the previous signal.



Figure 3. Sensor configuration on tripods – Test 1

Source: original photo due to informed parental consent

In test 2 (Figure 4), gymnasts had the task to quickly move over a distance of 3 m to turn off the visual signal with the letter “a” appearing on a single display out of the 10. Athletes had to turn off 20 light signals that were displayed as soon as the gymnast has turned off the previous signal.



Figure 4. Sensor configuration on tripods – Test 2

Source: original photo due to informed parental consent

We present below some of the technical features of this equipment.

Witty is designed as a test equipment but also as a training system recommended for sports where speed, reaction time and speed-agility combination are essential. Due to the timer and photocell-integrated radio system, the large colour display and the modern interface, the setup is relatively easy. The kit includes a free Windows software program called Witty Manager for importing test data and viewing them on numerical tables and graphs, which will be presented in this paper. With the help of this equipment, individualised databases and types of customised tests can be created according to the specifics of the sport.

Contents of the kit: 1 timer; 10 photocells; 2 reflectors; 10 tripods; 1 USB-PC cable; 1 wall power supply for charging the timer and 2 photocells at once.



Figure 5. Witty timer with colour display
(Witty User Manual, 2020)

Statistical analysis

Statistical data were collected by testing the research subjects with the help of Witty equipment. For each test, subject and repetition, as well as at group level, the following indicators of central tendency were measured: minimum and maximum values, mean, standard deviation and coefficient of variation.

Using these statistical data, it was possible to calculate the Spearman correlation coefficient in order to identify the connection between the resulting variables, namely: total duration of each (static and dynamic) test, height and weight of the tested subjects.

Research subjects and location

The research subjects are gymnasts belonging to the following sports clubs: CS UNEFS Bucharest, CSM Arad and CSM Ploiești – junior category, members of the individual and group national team. Their centralised training has started in November 2017 at the Junior National Olympic Centre in Arad, under the coordination of coach Daniela Chiriac.

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

Results and Discussion

As previously mentioned, motor skills were assessed using the Wireless training timer (Witty) equipment that allowed the measurement of reaction speed and execution speed in a static position, as well as the measurement of travel speed in combination with the other forms, in a dynamic action.

In the first situation, the chosen position was Standing on tiptoes without travelling or lowering the heel on the ground, and gymnasts had the

task to turn off 20 light signals in the shortest time possible. This task was created in order to simulate specific situations encountered when performing apparatus difficulty elements that require the use of handling techniques (especially small, medium or large throws) with fast action and no travel. It is important for gymnasts not to change their positions, not to make extra steps or lose their balance, because an apparatus difficulty is validated by judges only if performed without technical faults.

Analysing the routines of finalist gymnasts at the 2018 European Junior Championships held in Guadalajara (Spain) in the all-around event, we have found that, out of a total of 344 apparatus difficulty elements, 125 were based on a small throw and 55 of them were performed in the clubs event, being followed by elements performed with a large throw – 52 repetitions, and elements of rolling on minimum two large body segments – 36 repetitions. These difficulty elements are performed in limit situations such as: small throw without the hands outside the visual field and with rotation, catch from a small throw without the hands during a body rotation around the vertical axis, or a small throw with two clubs at a time outside the visual field during a body rotation on one leg around the vertical axis. All these handling actions require maximum concentration, fast reaction to the apparatus and quick spatial-temporal orientation in order to be performed safely, with low risk of failure.

Table 1. Summary table of additional criteria for dynamic elements with rotation valid for all apparatus during throw and/or catch

General criteria valid for all apparatus + 0.10 each time during throw of apparatus and/or during catch of apparatus	
Symbol	Description of the criteria and requirements
	Outside the visual control
	Without the help of the hands (not valid for direct catch in rotation with the arm for hoop, or mixed catch for rope and clubs)
	Catch during a rotation (only valid when performed together with the “outside the visual field” criterion)
	Under the leg/legs

Source: Fédération Internationale de Gymnastique (2018) - Code of Points

Table 2. Summary table of additional criteria for dynamic elements with rotation specified for each apparatus

Symbol	Specific criteria of the throw + 0.10 each time	Symbol	Specific criteria of the catch + 0.10 each time
	Passing through the apparatus during a throw (for rope and hoop)		Passing through the apparatus during catch (for rope and hoop)
	Throw after bounces on the floor/ throw after rolling on the floor		Direct re-throw/re-bound without any stops from different parts of the body or floor (for all apparatus)
	Throw of the open and stretched rope (held by one end or the middle)		Catch of the open and stretched rope held by one end with continuous movement of the rope after the catch
	Throw with rotation around its axis (for hoop), or rotation in the horizontal plane (for one or both clubs)		Direct catch with rolling of apparatus over the body
	Throws of 2 unlocked clubs, simultaneously, asymmetric or "cascade"		Catch of the rope with one end in each hand without support on another part of the body
	Throw on oblique plane (for hoop)		Catch of the ball with one hand
			Direct catch of the hoop in rotation
			Mixed catch of the rope or clubs

Source: FIG (2018) - Code of Points

Tables 1 and 2 are taken over from the *Code of Points 2017-2020*, Chapter 5.2, "Summary Table of Additional Criteria for Dynamic Elements with Rotation" (pp. 24-25).

Figure 6 and Table 3 show the results obtained by gymnasts for Witty test, together with the indicators of central tendency – Static test.

Experimental group gymnasts recorded an average of 12.23 seconds, with an average data spread and a difference of 8.85 seconds between minimum and maximum values.

Subject ES, who recorded the best total time, achieved values below the group average for each repetition but had constant performance throughout the test, without moments of loss of concentration or onset of

fatigue. The same can be said about 5 of the athletes with the best values recorded, while subjects in the last 7 places recorded at least once the highest value for a repetition, and the last-ranked gymnast recorded 7 out of 19 repetitions with the highest value and a single value below the group average.

Using the observation method and test data, we noticed that 7 athletes had problems locating the visual stimulus, meaning that the development of their complex reaction speed was at a low level.

Figure 6 shows that the average value for each of the 19 repetitions has an upward trend, with the lowest average value in the 1st repetition – 0.54 seconds, while the highest average value is identified in the 15th repetition – 0.82 seconds, and values over 0.6 seconds are recorded until the 19th repetition. The maximum value for a repetition is 2.64 seconds also in the 15th repetition, while the minimum value is 0.32 seconds in the 13th repetition.

Regarding the coefficient of variation of total duration, it is noted that there is an average data spread, the arithmetic mean being representative for the group, while the standard deviation has a low value, which indicates a high homogeneity of the group.

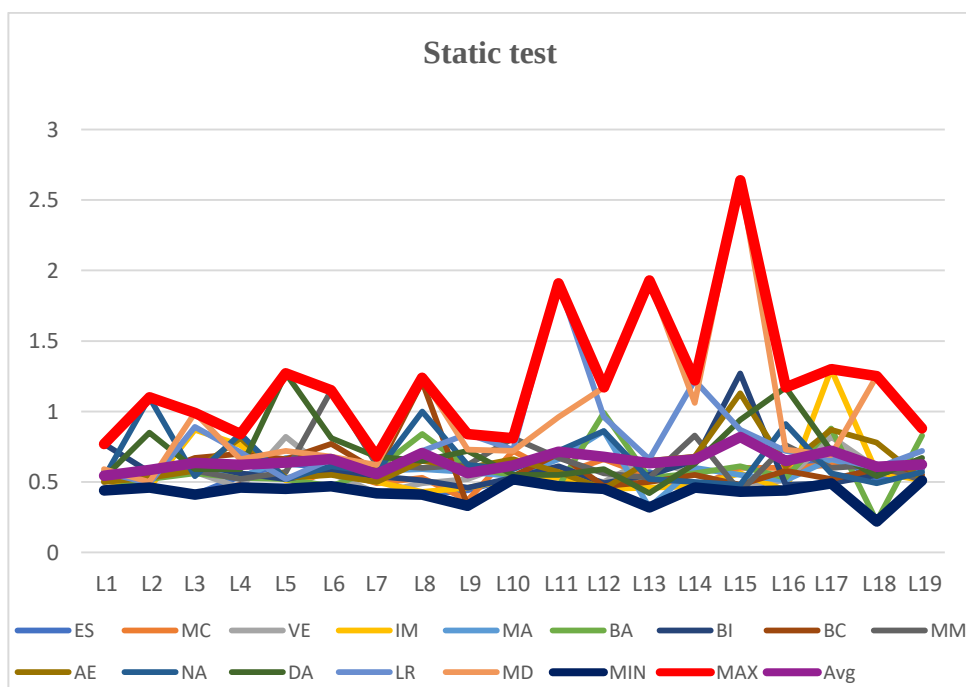


Figure 6. Witty – Static test

Source: Original figure resulting from research data

Table 3. Raw values for Witty – Static test

Source: Original data resulting from research design

Name initials	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	Total Time
ES	0.5	0.4	0.4	0.5	0.6		0.5	0.4	0.4	0.5	0.5	0.4	0.5	0.4	0.4	0.5		0.5	0.5	
	1	7	1	4	3	0.6	2	1	4	3	5	7	7	7	4	4	0.7	2	9	9.91
MC	0.5	0.4	0.4	0.4	0.5	0.4	0.5	0.3	0.7	0.5	0.6	0.5	0.6	0.5	0.4		0.6	0.6		
	1	6	2	8	5	9	9	3	7	2	5	6	4	6	0.6	0.6	2	1	0.6	10.26
VE		0.5	0.5	0.4	0.8	0.5	0.4	0.4	0.5	0.6	0.5		0.6	0.5	0.4	0.5	0.8		0.5	
	0.5	8	7	6	2	6	2	9	2	4	4	0.5	7	5	8	1	2	0.6	4	10.77
IM	0.5	0.4	0.8	0.7	0.5	0.5		0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5	
	1	6	7	6	1	6	0.5	3	6	2	3	5	6	7	6	4	1.3	7	1	10.87
MA	0.5	0.5	0.5	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.6	0.8	0.3		0.5	0.5	0.6	0.5		
	6	3	9	3	7	8	8	9	7	4	6	6	2	0.6	5	1	6	7	0.6	11.17
BA	0.4	0.5	0.5	0.5	0.5	0.4	0.5	0.8		0.5	0.4	0.9	0.5	0.5	0.6	0.5	0.8	0.2	0.8	
	4	2	6	3	2	7	9	4	0.6	5	7	9	3	6	1	3	8	2	3	11.24
BI	0.7	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.6	0.4	0.5	0.6	1.2	0.4	0.4	0.5	0.6	
	7	7	3	6	2	8	4	1	6	3	1	9	5	5	7	8	9	5	4	11.40
BC	0.5	0.5	0.6		0.6	0.7	0.5	1.2	0.3	0.5		0.4		0.5	0.4	0.5	0.5	0.5	0.5	
	7	5	7	0.7	6	7	8	1	3	4	0.7	7	0.5	5	8	8	2	9	5	11.52
MM	0.5	0.5	0.5	0.5	0.5	1.1	0.6		0.6	0.8	0.6	0.5	0.5	0.8	0.4	0.7		0.6	0.5	
	3	9	8	2	7	5	2	0.6	2	1	7	6	3	3	3	6	0.6	2	1	12.1
AE		0.5	0.5	0.8	0.5	0.5		0.6		0.6	0.5	0.4	0.6	0.6	1.1	0.6	0.8	0.7	0.5	
	0.5	3	8	1	3	5	0.5	5	0.6	6	7	5	5	8	3	1	7	8	2	12.17
NA	0.5		0.5	0.8	0.5	0.6	0.5		0.6	0.5	0.7	0.8	0.5		0.4	0.9	0.5	0.4	0.5	
	3	1.1	4	4	2	1	7	1	2	9	2	6	2	0.5	8	1	6	9	7	12.53
DA	0.5	0.8	0.5	0.5	1.2	0.8	0.6	0.6	0.7	0.5	0.5	0.5	0.4	0.6	0.9	1.1	0.7	0.5	0.6	
	3	5	9	7	1	8	5	2	5	5	9	2	3	4	7	2	4	7	13.47	
LR	0.5	0.4	0.8	0.7	0.5	0.6	0.5	0.7	0.8	0.7	1.9	0.9	0.6	1.2	0.8	0.7	0.6		0.7	
	7	9	9	1	2	6	5	2	4	3	1	6	6	2	7	2	7	0.6	2	15.01
MD	0.5		0.9	0.6	0.7	0.6	0.6	1.2	0.7	0.7	0.9	1.1	1.9	1.0	2.6	0.7	0.6	1.2	0.8	
	9	0.5	9	6	2	8	2	4	3	2	6	7	3	6	4	3	9	5	8	18.76
MIN	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.5	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.2	0.5	
	4	6	1	6	5	7	2	1	3	2	7	5	2	6	3	4	9	2	1	9.91
MAX	0.7		0.9	0.8	1.2	1.1	0.6	1.2	0.8	0.8	1.9	1.1	1.9	1.2	2.6	1.1		1.2	0.8	
	7	1.1	9	4	7	5	8	4	4	1	1	7	3	2	4	7	1.3	5	8	18.76
Avg	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.7	0.5	0.6	0.7	0.6	0.6	0.6	0.8	0.6	0.7	0.6	0.6	
	4	9	4	2	4	6	5	1	6	2	1	8	3	6	2	5	2	1	2	12.23
Std Dev	0.0	0.1	0.1	0.1	0.2	0.1	0.0	0.2	0.1	0.1	0.3	0.2	0.3	0.2	0.5	0.2	0.2	0.2	0.1	
	8	8	7	2	1	7	7	4	0	6	4	9	3	9	0	0	2	2		2.30
CV (%)	13.	30.	26.	20.	32.	25.	11.	38.	25.	15.	51.	35.	60.	34.	71.	30.	28.	36.	18.	
	82	24	69	11	74	17	92	44	52	57	15	82	94	68	78	48	38	08	56	18.78

Figure 7 and Table 4 show the results obtained by gymnasts for Witty test, together with the indicators of central tendency – Dynamic test.

Experimental group gymnasts recorded an average of 1:14:81, therefore a homogeneous result, with a difference of 15.90 seconds between minimum and maximum values.

The same subject ES has the best values in the dynamic test too, with total duration of 1:07.99 and the best 7 values recorded for each repetition as minimum values. However, in the 12th repetition, the gymnast records 5.88 seconds, which is a maximum value at group level for that repetition and

above the average of 3.94 seconds. We can assume that the gymnast had a moment of loss of concentration in that repetition, excluding the possibility of fatigue because the next repetitions returned to previous values.

Regarding the minimum values recorded for each repetition, it is noted that 7 out of the 14 subjects have recorded a minimum value at least once, thus ranking on the top 8 positions. Four of these athletes have never recorded a minimum value per repetition.

Subject MD, who recorded the highest total value in the static test, shows a moment of lack of concentration in the 18th repetition, ranking the second last in the overall ranking for this test.

Figure 7 reveals that the average value does not show very large statistical variations between the 19 values recorded for each repetition. The lowest average value, 3.77 seconds, is recorded in the 1st (as in the static test) and 15th repetitions, while the highest average value, 4.20 seconds, is recorded in the 16th repetition. The highest value is recorded in the 18th repetition, 9.83 seconds, while the lowest value is recorded in the 1st repetition, 3.12 seconds.

The value of the coefficient of variation is very good, so the experimental group is homogeneous, the data spread is very low, and the average is representative for the group.

Analysing the average minimum value and the lowest value recorded for a repetition, we notice that, in both tests, gymnasts have the lowest values in the 1st repetition.

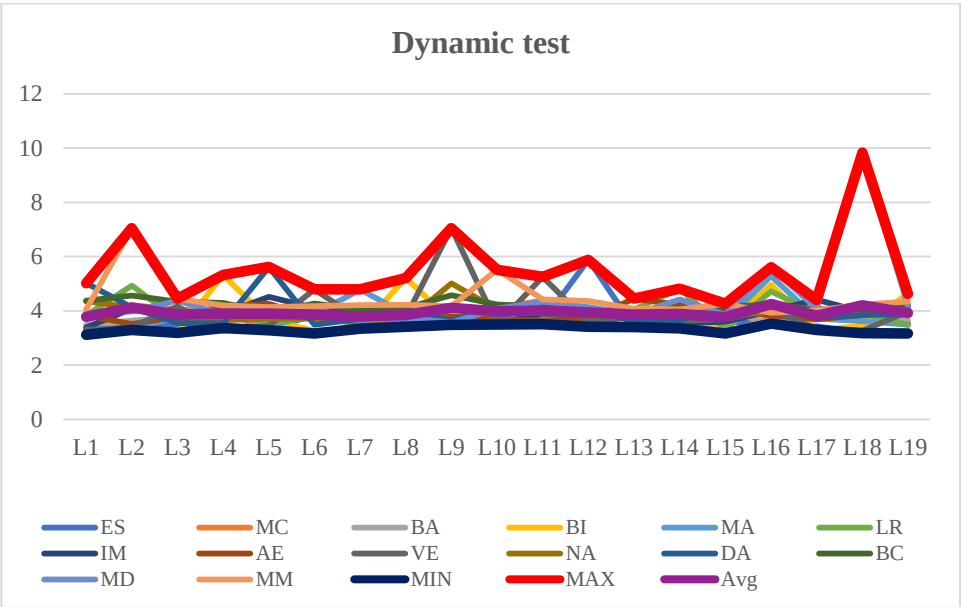


Figure 7. Whitty – Dynamic event
Source: Original figure resulting from research data

Table 4. Raw values for Whitty – Dynamic test

Name initials	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	Total time
ES	3.12	3.3	3.5	3.37	3.32	3.86	2	3.42	3.71	3.59	3.62	5.88	1	3.35	3.6	3.54	3	3.18	3.17	1:07.99
MC	3.78	4.21	5	3.99	3.29	3.17	2	3.53	3.54	4.13	4.37	3.53	3.4	3.35	7	3.75	9	3.89	3.57	1:09.83
BA	3.48	3.65	6	3.67	3.8	3.79	2	3.75	4.16	3.92	3.71	3.6	1	3.72	1	3.53	3.9	3.81	3.65	1:11.44
BI	3.13	3.34	9	5.32	3.67	3.27	3.3	5.21	3.63	4.08	3.61	3.41	6	3.57	1	4.96	3.3	3.44	4.63	1:11.97
MA	3.29	3.39	6	3.33	3.43	3.87	4.7	3.88	3.62	3.86	3.51	3.57	1	4.01	3	5.29	2	3.62	3.49	1:12.07
LR	3.83	4.93	8	3.96	3.55	3.77	1	3.6	3.48	3.52	3.59	3.55	4	4.82	2	4.72	2	3.92	3.48	1:13.19
IM	3.39	4.08	2	3.89	4.52	4.11	1	3.58	3.63	3.53	3.89	3.88	4	3.55	3.6	4	4.4	3.96	4.21	1:13.90
AE	3.83	3.51	9	4.17	4.26	3.76	1	3.64	3.8	3.67	3.64	3.71	5	4.22	1	3.83	9	3.85	4.18	1:13.92
VE	3.3	3.4	6	3.27	3.45	4.79	8	3.76	7.05	3.5	5.25	3.58	7	3.63	9	4.05	4	3.27	3.98	1:14.92
NA	4.35	4.13	6	3.66	3.72	3.72	3.6	3.61	5.01	4.05	3.92	3.93	6	3.93	1	3.98	8	3.94	4.02	1:15.18
DA	5.02	4.13	5	3.54	5.62	3.49	3.7	3.93	3.64	4.12	4.14	4.08	1	3.65	4	4.13	5	3.85	3.88	1:16.07

BC	4.37	4.56	4	4.29	3.92	4.27	4	4.11	4.58	4.24	4.16	3.96	4	4.09	1	4.27	4	4.05	4.09	1:19.53
MD	3.9	3.98	7	3.87	3.91	4.07	6	3.74	3.57	4.08	4.34	4.14	7	4.42	6	5.61	7	9.83	4.17	1:23.46
MM	4.05	7.05	5	4.2	4.14	4.17	1	4.22	4.17	5.52	4.42	4.36	8	4.06	6	3.93	2	4.24	4.34	1:23.89
MIN	3.12	3.3	9	3.37	3.29	3.17	4	3.42	3.48	3.5	3.51	3.41	3.4	3.35	7	3.53	3.3	3.18	3.17	1:07.99
MAX	5.02	7.05	5	5.32	5.62	4.79	9	5.21	7.05	5.52	5.25	5.88	5	4.82	6	5.61	1	9.83	4.63	1:23.89
Avg	3.77	4.12	6	3.90	3.90	3.87	9	3.86	4.11	3.99	4.01	3.94	6	3.88	7	4.26	1	4.20	3.92	1:14.81
Std Dev	0.55	0.98	7	0.53	0.61	0.42	7	0.45	0.96	0.51	0.48	0.65	0	0.42	4	0.64	1	1.65	0.40	4.67
CV (%)	14.4	23.7	9.4	13.4	15.7	10.7	9.8	11.6	23.2	12.8	11.9	16.4	7.8	10.8	8.9	15.1	8.2	39.1	10.2	6.2%

Source: Original data resulting from research design

Spearman correlation between total duration per test and anthropometric parameters is shown in Table 5.

Table 5. Spearman correlation between total duration per test and anthropometric parameters

Source: Original data resulting from research design

Parameters	Height	Weight	Total time – Static test	Total time – Dynamic test
Height	1	$r_s = 0.77058$ p (2-tailed) = 0.00126	$r_s = 0.01128$ p (2-tailed) = 0.96948	$r_s = 0.01353$ p (2-tailed) = 0.96338
Weight	$r_s = 0.77058$ p (2-tailed) = 0.00126	1	$r_s = 0.12182$ p (2-tailed) = 0.67824	$r_s = 0.20156$ p (2-tailed) = 0.48957
Total time – Static test	$r_s = 0.01128$ p (2-tailed) = 0.96948	$r_s = 0.12182$ p (2-tailed) = 0.67824	1	$r_s = 0.64835$ p (2-tailed) = 0.01214
Total time – Dynamic test	$r_s = 0.01353$ p (2-tailed) = 0.96338	$r_s = 0.20156$ p (2-tailed) = 0.48957	$r_s = 0.64835$ p (2-tailed) = 0.01214	1

Height and Weight - By normal standards, the association between the two variables would be considered statistically significant.

Height and Static test - By normal standards, the association between the two variables would not be considered statistically significant.

Height and Dynamic test - By normal standards, the association between the two variables would not be considered statistically significant.

Weight and Static test - By normal standards, the association between the two variables would not be considered statistically significant.

Weight and Dynamic test – By normal standards, the association between the two variables would not be considered statistically significant.

Static test and Dynamic test - By normal standards, the association between the two variables would be considered statistically significant.

Conclusion

The key features of these data, as well as previous analysis of junior routines for the 2017-2020 Olympic cycle, have led us to the conclusion that, in order to get a high score for apparatus difficulty/mastery, more difficulty elements should be added, which requires an increase in all kinds of speed involved by the technique of a specific event.

- In test 1 – for (psycho)motor skills, experimental group gymnasts recorded an average of 12.23 seconds, with an average data spread and a difference of 8.85 seconds between minimum and maximum values.

- In test 2 – for (psycho)motor skills, experimental group gymnasts recorded an average of 1:14:81, therefore a homogeneous result, with a difference of 15.90 seconds between minimum and maximum values.

Preliminary data obtained in this study represent a starting point for the experimental programme that will allow assessing the effectiveness of programmes aimed at increasing both the execution speed and reaction speed. Analysing the international literature, we find that very few studies have been conducted on this topic, which makes it difficult to compare the development level of junior gymnasts.

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References

Agopyan, A. (2014). Analysis of body movement difficulties of individual elite rhythmic gymnasts at London 2012 Olympic Games Finals. *Journal of Scientific Research*, 19(12), 1554-1565.
<https://doi.org/10.5829/idosi.mejsr.2014.19.12.81263>

Agopyan, A., & Serdil Ors, B. (2019). An analysis of variations in body movement difficulty of 2016 Olympic Games rhythmic gymnast candidates.

- International Journal of Performance Analysis in Sport*, 19(9), 417-434.
<https://doi.org/10.1080/24748668.2019.1617017>
- Ávila-Carvalho, L., Klentrou, P., Palomero, M., & Levre, E. (2012). Analysis of the technical content of elite rhythmic gymnastics group routines. *Open Sports Science Journal*, 5, 146-153.
<http://dx.doi.org/10.2174/1875399X01205010146>
- Chiat, L. F., & Ying, L. F. (2012). Importance of music learning and musicality in rhythmic gymnastics. *Procedia – Social and Behavioral Sciences*, 46, 3202-3208.
<https://doi.org/10.1016/j.sbspro.2012.06.037>
- Fédération Internationale de Gymnastique (FIG). (2018). Rhythmic gymnastics. *Gymnastics Sport*. ,
https://www.gymnastics.sport/publicdir/rules/files/en_rg%20cop%202017-2020%20with%20errata%20dec.%2017.pdf
- Fédération Internationale De Gymnastique (FIG). (2018). *Code of Points 2017-2020. Rhythmic Gymnastics* [Updated version 1st of February 2018 , valid through 31 Dec. 2021].
https://www.gymnastics.sport/publicdir/rules/files/en_RG%20CoP%202017-2020%20with%20Errata%20Dec.%2017.pdf
- Hashimoto, M., Kida, N., & Nomura, T. (2017). Characteristics of women's rhythmic gymnastics from the perspective of "body difficulty" and performance time. *Advances in Physical Education*, 7(3), 260-273.
<https://doi.org/10.4236/ape.2017.73021>
- Jastrzebskaia, N., & Titov, Y. (1999). *Rhythmic gymnastics*. Human Kinetics.
- Kritikou, M., Donti, O., Bogdanis, G., Donti, A., & Theodorakou, K. (2017). Correlates of artistry performance scores in preadolescent rhythmic gymnasts. *Science of Gymnastics Journal*, 9(2), 165-177.
<https://pdfs.semanticscholar.org/2313/4a31f898f087e2760cf57e7729cee45bd888.pdf>
- Leandro, C., Ávila-Carvalho, L., Sierra-Palmeiro, E., & Bobo Arce, M. (2017). Judging in rhythmic gymnastics at different levels of performance. *Journal of Human Kinetics*, 60, 159-165. <https://dx.doi.org/10.1515%2Fhukin-2017-0099>
- Leandro, C., Avila-Carvalho, L., Sierra-Palmeiro, E., & Bobo-Arce, M. (2016). Departure difficulty score vs final difficulty score. The effect of performance in elite rhythmic gymnastics. *Athens Journal of Sports*, 3(3), 169-178. <https://doi.org/10.30958/ajspo.3-3-1>
- Manos, M. (2008). *Gimnastică ritmică – Capacitatea de performanță* [Rhythmic gymnastics – Performance capacity]. BREN.

- Miletić, Đ., Katić, R., & Malesš, B. (2004). Some anthropologic factors of performance in rhythmic gymnastics novices. *Collegium Antropologicum*, 28(2), 727-737. <https://pubmed.ncbi.nlm.nih.gov/15666605/>
- Moskovljević, L., Radisavljević, L., & Dabović, M. (2013). The speed of progress in the apparatus handling technique in rhythmic gymnastics. *Fizička Kultura*, 67(1), 33-39. <https://doi.org/10.5937/fizkul1301033M>
- Purenovic-Ivanovic, T., Popovic, R., Stankovic, D., & Bubanj, S. (2016). The importance of motor coordination abilities for performance in rhythmic gymnastics. *Facta Universitas*, 14(1), 63-74. <http://casopisi.junis.ni.ac.rs/index.php/FUPhysEdSport/article/view/1517/1108>
- Sierra-Palmeiro, E., Bobo-Arce, M., Perez-Ferreiros A., & Fernandez-Villarino, M. (2019). Longitudinal study of individual exercise in elite rhythmic gymnastics. *Frontiers in Psychology*, 10(1496), 1-7. <https://dx.doi.org/10.3389%2Ffpsyg.2019.01496>
- Trifunov, T., & Dobrijevic, S. (2013). The structure of difficulties in the routines of the best world and Serbian rhythmic gymnasts. *Physical Culture*, 67(2), 120-129. <https://doi.org/10.5937/fizkul1302120T> [The English version retrieved from <https://pdfs.semanticscholar.org/d287/fdcfcd5502bb30352c6086b9175e87983606.pdf>
- Witty User Manual. (2020). MicroGate WIT005 Witty Sem User Manual Witty EN. *Training Microgate*. <https://training.microgate.it/sites/default/files/manuali/Witty-UserManual-EN.pdf>