

## THE BALANCE ABILITY OF TOP-LEVEL FEMALE RHYTHMIC GYMNASTS: DOES IT PREDICT THEIR PERFORMANCE SCORES?

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### Abstract

Rhythmic gymnastics (RG) is an extremely demanding sport that has a positive effect on the exerciser's motor status. However, in order to be able to acquire RG contents, the existence of certain minimally developed motor skills, including the ability of postural control and body stabilisation during dynamic movements, is of vital importance. The main objective of this study is to assess the role, contribution and influence of balance ability on performance scores in RG. The sample consisted of 126 international-level female rhythmic gymnasts (RGs), divided into five age categories (15 seniors, 25 juniors, 26 advanced-level RGs, 38 intermediate-level RGs, and 22 beginners). Their baseline characteristics (age, body height and mass, body mass index) were established, along with their balance abilities (balance on toes (left/right leg) test, single leg (left/right) balance test – eyes closed, double pivot in *passé* test). The data was analysed (descriptive statistics, Kolmogorov-Smirnov test, multivariate and univariate regression analysis) using SPSS 21.0. The results of the multivariate regression analysis indicate the existence of a statistically significant influence of the balance ability of advanced-level RGs, as well as the RGs comprising the rest of the sample, on their performance scores ( $p=0.01$  and  $p=0.00$ , respectively), with statistically significant individual contributions of the balance on toes test – right leg (advanced-level RGs:  $p=0.01$ , total sample:  $p=0.02$ ), and dynamic balance (total sample:  $p=0.00$ ). The final conclusion is that balance ability is a significant predictive factor of RGs' performance scores, with a variance explanation of 35% (advanced-level RGs), i.e. 24% (entire sample).

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**Key words:** rhythmic gymnastics, static balance, dynamic balance, age categories, success.

## СПОСОБНОСТ РАВНОТЕЖЕ ВРХУНСКИХ РИТМИЧКИХ ГИМНАСТИЧАРКИ: ДА ЛИ ПРЕДВИЂА РЕЗУЛТАТЕ ЊИХОВИХ ПЕРФОРМАНСИ?

### Апстракт

Ритмичка гимнастика (РГ) је изузетно захтеван спорт који позитивно утиче на моторички статус вежбача. Међутим, да би се уопште могло приступити усвајању РГ садржаја, неопходно је постојање одређеног минимума развијености свих моторичких способности, међу којима су постурална контрола и способност стабилизовања тела током динамичних кретања од виталног значаја. Основни циљ овог истраживања је да утврди значај, допринос и утицај способности равнотеже на успех у ритмичкој гимнастици. Узорак испитаника чинило је 126 ритмичких гимнастичарки, распоређених у пет узрасних категорија (15 сениорки, 25 јуниорки, 26 кадеткиња, 38 пионирки, и 22 млађе пионирке). Утврђене су њихове основне карактеристике (узраст, телесна висина и маса, индекс телесне масе), као и статус способности равнотеже (тест равнотеже на прстима (лева/десна) нога, тест равнотеже на једној ноzi (лева/десна нога) – затворене очи, дупли окрет у *passé* позицији). Подаци су анализирани (дескриптивна статистика, тест Колмогоров-Смирнов, мултиваријантна и униваријантна регресиона анализа) применом SPSS 21.0. Резултати мултиваријантне регресионе анализе указали су на постојање статистички значајног утицаја способности равнотеже кадеткиња, као и укупног узорака, на успех у РГ ( $p=0.027$  и  $p=0.00$ , редом), при чему су утврђени статистички значајни појединачни доприноси успеху у РГ код равнотеже на прстима на десној ноzi (кадеткиње:  $p=0.01$ , укупан узорак:  $p=0.02$ ) и код динамичке равнотеже (укупан узорак:  $p=0.00$ ). Крајњи закључак је да је способност равнотеже значајан предиктивни фактор перформанси у РГ, са објашњењем варијансе од 35% (код кадеткиња), односно 24% (укупан узорак).

**Кључне речи:** ритмичка гимнастика, статичка равнотежа, динамичка равнотежа, узрасне категорије, успех.

### INTRODUCTION

Although it is widely acknowledged that talent is indispensable for top-level performance, the position and role of abilities (cognitive, perceptual and motor) in the actualisation of motor skills have long been established (Giannitsopoulou et al., 2003). Motor balance is the ability of keeping the body in a stable position, and it implies the involvement of neuromuscular structures. We distinguish between static balance (the ability of maintaining the stable position of a body that is not in motion) and dynamic balance (the ability of maintaining a stable position in conditions of movement). Vestibular, kinesthetic, tactile and optical analysers play a significant role in achieving a balanced position (Penčić, 2014), but the most important factors in maintaining balance are: genetic determination (the he-

editary coefficient of this ability is very high, which makes the work on developing balance rather complex, specific and difficult (Кукољ, 2006)), the condition of the vestibular apparatus, age (young healthy people have better balance ability results compared to children), support surface, the height of the body's center of gravity, the position of free body parts, training, strength, coordination, flexibility, emotional state (Каярнар, 2011), fatigue (Wilkins et al., 2004; Pau et al., 2020), and even the time of day (di Cagno et al., 2014). Balance ability is one of the fundamental aspects of movement-coordination qualities, and it has a direct bearing on learning and applying new abilities. It is also a prerequisite for success in sports activities, and essential for the development of fundamental motor skills and for injury prevention (Fotios et al., 2013). Sports training enhances joint strength, range of motion, and neuromuscular coordination, all of which contribute to an improvement in balance ability (Kesilmiş et al., 2017).

When it comes to the complexity of the required abilities, rhythmic gymnastics (RG) represents an extremely demanding aesthetic and artistic sports discipline – a rhythmic gymnast has the task of coordinating body technique with a technique of handling one of the five RG apparatuses (ball, hoop, rope, ribbon and clubs), while simultaneously demonstrating an extreme flexibility of all parts of the body, and an excellent sense of rhythm, space and time. It is a sport that imposes high demands on body size, build and composition, as well as the motor skills of performers, especially high-level performers (Пуреновић-Ивановић, 2017). Research conducted with the aim of identifying the predictors of success in RG showed that it is necessary for almost all motor skills to be well pronounced in order to attain great achievements in this sport, but given the fact that a competition routine in RG consists of complex motor elements (jumps/leaps, balances, rotations/pivots/turns, pre-acrobatic elements, dance steps, full body waves), the performance of which requires a well-developed balance ability (Vuillerme et al., 2001; Tincea, 2020), both static and dynamic (Gateva, 2016), it is quite clear that this motor ability occupies a very important place in the physical preparation of rhythmic gymnasts (RGs). In recent years, balances as body difficulties have occupied an increasingly important place in the performance of RG routines – during a minute and a half, which is how long an individual routine lasts, a rhythmic gymnast realises as many as twenty to twenty-two elements of static and dynamic balance (Poliszczuk et al., 2012). It is important to emphasise that this motor ability is one of the elements that RG judges evaluate very strictly, and its loss during a routine performance affects the final score. Therefore, the ability of RGs to hold well-defined balance positions and maintain them for a minimum period of time so that judges can make an adequate assessment of them is a decisive factor for success in this sport (Palomares et al., 2019). That is why it is very important to develop this motor ability, especially in girls of younger school age, when the pace of balance development is the most intense (Penčić, 2014; Dobrijević et al., 2016). In

addition, numerous studies have compared balance ability among athletes in different sports, and the highest level of this ability was recorded precisely in RGs (Bressel et al., 2007; Hrysomallis, 2011; Shahheidari et al., 2012), which is not a surprise considering that a significant part of training in RG derives from classical ballet exercises, and ballet is ‘crowned’ with supreme balance (Prochazkova et al., 2014).

It has been repeatedly proven through examination that RG has a good impact on the performer’s body, particularly on their motor status – RG training enables the development of motor skills, and the improvement of abilities such as flexibility, balance, coordination, and strength (Miletić et al., 2004; Pavlova, 2011; Poliszczuk et al., 2012; Fotios et al., 2013; Penčić, 2014). However, a certain minimum level of development of all motor skills is necessary in order to be able to acquire RG content at all, among which postural control (Scursatone et al., 2015) and an ability to stabilise the body during dynamic movements are of vital importance (Kesilmiş et al, 2017). Thus, having in mind that the important abilities needed to succeed in some tasks vary with the athletes’ age (Fleishman, 1972; according to Kioumourtzoglou et al., 1997), and that the necessity of monitoring balance ability in RGs is evident, the aim of this research is to determine the influence of balance ability on the performance scores of high-level female RGs of different age categories.

## *METHODS*

### *Participants*

The sample of examinees used in this research is comprised of international-level female RGs. The research included 126 female participants – individual competitors of all age categories, and only those female RGs who had previously voluntarily agreed to participate in this research (those 18 years of age, or older), or those underaged female participants whose parents gave written consent for their participation.

### *Ethical Considerations*

The study protocol was approved by the local ethics committee (No. 04-610), and testing was performed in accordance with the ethical standards of the Declaration of Helsinki (WMA, 2013). Consent was given by the Gymnastics Federations and/or Expert committees for RG, club coaches, and by RGs’ parents, i.e. personally by the adult participants in this study.

### *Measures and Procedures*

Measuring was carried out using the same instruments, by the same measurer, according to the International Biological Program (Weiner & Lourie, 1969), in an adequately lit room with optimal climatic conditions, and

with the participants in their underwear. The basic characteristics of the participants comprising the sample were defined by the following variables: age (Age), in 0.1 years; body height (Height), in 0.1 cm; body mass (Weight), in 0.1 kg; and body mass index (BMI), in 0.1 kg/m<sup>2</sup>. By interviewing the RGs, we collected data on their age (date of birth). The Martin anthropometer was used to obtain the RGs' body height, while body mass and body mass index were assessed with a tetrapolar bioelectrical impedance device – *Omron BF511* (Kyoto, Japan), after entering the data on participants' age, gender and body height. Finally, the testing of the static and dynamic balance ability of the RGs was undertaken, and only a stopwatch was used as equipment for its realisation. Namely, for the estimation of balance abilities, the tests proposed by Jastrjemskaia & Titov (1998, pp. 139–141) were used. These three instruments (the first two of which are paired tests, and the third and fourth require the participant's eyes to be closed) are intended to monitor the level of balance ability of RGs: balance on toes – left leg /BTOE-L/ in 0.1 s, and balance on toes – right leg /BTOE-R/ in 0.1 s; single leg balance – left leg /B1LEG-L/ in 0.1 s, and single leg balance – right leg /B1LEG-R/ in 0.1 s; and double turn in *passé* /2TUR/ in the number of successful attempts (turns). The criterion variable in this research was the participants' competitive/performance scores, i.e. final score /FINS/ in points, and, considering the fact that in RG there are inevitable differences between competitors of different age and competition programme categories, it was necessary to 'equalise' the participants in terms of their final score. Therefore, in order to optimally define the criterion variable, the mean value of the total points achieved in the competition was taken (final points divided by the number of routines performed in the competition) for the final score of each study participant.

#### *Statistical Analysis*

The descriptive statistics [average value (Mean), Standard Deviation (SD), Minimum (Min), Maximum (Max)] were summarised for all variables and for each of the five age categories, as well as for the entirety of the sample. Normality was tested using the one-sample Kolmogorov-Smirnov test (K-S). In order to determine the significance and the strength of the linear relationship between balance ability and performance scores, a Pearson's correlation coefficient ( $r$ ) was applied for normally distributed variables, and Spearman's correlation coefficient was applied for variables with statistically significant deviations from normal data distribution. Multiple regression analysis ( $R$  – multiple correlation coefficient,  $R^2$  – coefficient of determination of multiple correlation, Adjusted  $R^2$  – adjusted coefficient of determination of multiple correlation<sup>1</sup>,  $F$  –  $F$ -test value,  $p$  – significance of multiple regression) was performed with the aim of determining the amount of variance in balance ability's influ-

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<sup>1</sup> When dealing with the small sample of study participants, the value of  $R^2$  is "an overly optimistic estimate of an actual value of coefficient of determination" (Pallant, 2010, p. 160), so the interpretation of Adjusted  $R^2$ , which gives a better estimate, is recommended.

ence on the success rate of RGs' performance, and for the purpose of determining the independent contributions of each of the independent variables to the prediction of the dependent variable, i.e. FINS. Afterwards, univariate regression analysis was performed ( $r$  – correlation coefficient,  $r$  – coefficient of partial correlation,  $b$  – standardised regression coefficient,  $\text{Std.Err. of } b$  – standardised error of regression coefficient,  $t$  – vector of standardised regression coefficient,  $p$  – significance of beta coefficient). The level of significance was set at  $p < 0.05$ , and the data was analysed using the Statistical Package for the Social Sciences, version 21.0 (IBM SPSS 21.0, SPSS Inc, Chicago, USA).

### RESULTS AND DISCUSSION

The baseline characteristics of the entire sample and the sub-samples (age categories) are presented in Table 1, and the descriptive statistics data of the assessed balance ability is presented in Table 2.

Inspecting Table 1, and based on the BMI cut-off points for girls of different ages (CDC, 2000), it can be stated that the BMI value of most of the RGs ( $n=115$ , or 91.27%) is within the normal range; only a few of them are below the recommended values ( $n=10$ , or 7.94%), and one RG from the beginners category has a BMI of 18.7 kg/m<sup>2</sup>, with the upper limit for a normal BMI for a girl of her age is 17 kg/m<sup>2</sup>.

Table 1. Baseline characteristics of the study participants

Age categories	Variables	Age (yrs)	Height (cm)	Weight (kg)	BMI (kg/m <sup>2</sup> )	FINS (pts)
Seniors ( $n=15$ )	<i>Mean±SD</i>	17.53±1.37	164.56±6.83	55.51±4.91	20.48±1.16	9.29±1.91
	<i>Min – Max</i>	16.16 – 20.34	150.0 – 178.2	47.4 – 67.0	19.0 – 23.3	5.53 – 11.83
Juniors ( $n=25$ )	<i>Mean±SD</i>	14.53±0.74	162.94±7.05	48.61±6.16	18.23±1.4	9.34±1.54
	<i>Min – Max</i>	13.3 – 15.82	146.1 – 176.7	31.0 – 62.7	14.5 – 20.4	6.06 – 11.38
Advanced-level RGs ( $n=26$ )	<i>Mean±SD</i>	12.25±0.89	151.31±8.72	38.99±8.01	16.83±1.94	7.86±1.58
	<i>Min – Max</i>	10.57 – 13.8	136.0 – 164.4	25.5 – 53.2	13.8 – 21.4	4.3 – 10.45
Intermediate-level RGs ( $n=38$ )	<i>Mean±SD</i>	10.12±0.8	139.93±5.96	29.96±4.31	15.24±1.28	7.92±1.47
	<i>Min – Max</i>	8.71 – 12.02	125.1 – 151.4	22.6 – 40.2	12.7 – 18.9	4.4 – 10.38
Beginners ( $n=22$ )	<i>Mean±SD</i>	8.04±0.75	128.39±5.73	25.28±2.85	15.31±1.03	7.18±1.15
	<i>Min – Max</i>	6.67 – 9.08	120.1 – 139.3	20.8 – 30.8	13.6 – 18.7	4.55 – 8.75
Total sample ( $N=126$ )	<i>Mean±SD</i>	11.95±3.09	147.76±14.61	37.75±11.72	16.79±2.26	8.22±1.69
	<i>Min – Max</i>	6.67 – 20.34	120.1 – 178.2	20.8 – 67.0	12.7 – 23.3	4.3 – 11.83

Legend:  $n$ ,  $N$  – number of study participants, RGs – rhythmic gymnasts, Mean – average value, SD – standard deviation, Min – minimum, Max – maximum, BMI – body mass index, FINS – final score, yrs – years, pts – points.

In addition to flexibility, explosive power in the lower extremities, and coordination, the ideal motor base for the successful execution of RG-specific content also includes a highly developed ability to balance. In RG balances belong to body difficulties (in addition to jumps and turns), and

in every routine, with or without an apparatus, a rhythmic gymnast must demonstrate a mastery of complex balance difficulties as a characteristic structural group. Both types of balance prevail and are manifested in the execution of waves, dance steps, elements of rotation (turns and pivots), or the maintaining of single leg balance on tip-toes (most often on the so-called *relevé* – high rise of heel, less often than on a full foot), with simultaneous or additional work of the free leg and other body parts, synchronised with apparatus handling (Sanader, 2005). The status of the study participants' balance ability is presented in Table 2. What is noticeable is a statistically significant absence of a normal distribution of data (Sig.=.04) for the balance test performed with eyes closed (B1LEG-L and B1LEG-R) in intermediate-level RGs and beginners. A comparison with the rating scale (Jastrjemskaia & Titov, 1998, 140), where a high percentage of insufficient results was recorded in these tests (over 60% of RGs of all age categories achieved insufficient results on these tests), confirms that balance with eyes closed was a difficult task for the study's participants. In this case, this outcome is not unexpected considering that RG is a highly visual sport (Potgieter, 2007), not in terms of the aesthetics of RG movements and appearance, but rather in terms of how crucial eyesight is for the successful execution of coordinated movements and RG apparatus technique. The fact that vision is best equipped to stabilise extremely low frequencies of sway could be another explanation for the poor results on the static balance tests conducted with eyes closed. The integration of information from the vestibular, proprioceptive, and visual sensory systems, each of which has a unique but overlapping working frequency range that affects its impact on postural control in different settings (Redfern et al., 2001), is particularly important for postural control. Sensory conflicts, which typically happen when proprioceptive and/or visual cues diverge from vestibular information, pose a challenge to the posture control system. This kind of situation can cause worry and anxiety, and those emotional reactions can have an impact on how effectively a person achieves and performs in a number of daily activities (Ristić & Zlatković, 2021).

The intercorrelation matrices of each of the five sub-samples are not shown, but what is noticeable is that both the strength of correlations between the variables and the number of statistically significant intercorrelations increase as the age of the RGs decreases. Observing the intercorrelations of variables of the total sample of RGs (Table 3) shows that all predictor variables have a statistically significant correlation with the performance score in RG, but they are weak (B1LEG-L:  $r=0.21$ ,  $p<0.05$ ; B1LEG-R:  $r=0.23$ ,  $p<0.05$ ; BTOE-L:  $r=0.36$ ,  $p<0.01$ ) to moderate (BTOE-R:  $r=0.42$ ,  $p<0.01$ ; 2TUR:  $r=0.45$ ,  $p<0.01$ ). Also, all predictor variables correlate statistically significantly with each other, and the intercorrelations are mostly of medium strength (a strong correlation was recorded in the case of the static balance test – BTOE).

Table 2. Balance ability in RGs of different age categories

Age categories	Variables	BTOE		B1LEG		2TUR
		L	R	L	R	
Seniors (n=15)	Mean±SD	17.01±9.14	16.81±9.19	9.37±6.73	11.81±9.78	24.87±16.47
	Min–Max	2.74 – 33.04	6.37 – 36.28	2.31 – 30.98	3.19 – 32.0	8.0 – 53.0
	K-S (Sig.)	.991	.597	.279	.325	.267
Juniors (n=25)	Mean±SD	17.73±10.36	16.06±11.87	11.21±10.39	13.36±11.57	19.68±16.77
	Min–Max	3.2 – 46.69	2.26 – 55.06	2.69 – 39.25	2.08 – 46.86	2.0 – 70.0
	K-S (Sig.)	.851	.395	.175	.076	.347
Advanced-level RGs (n=26)	Mean±SD	20.56±18.07	21.99±17.09	9.45±5.68	11.47±10.04	16.96±18.06
	Min–Max	1.67 – 62.77	1.6 – 60.38	3.03 – 24.44	1.59 – 37.88	1.0 – 70.0
	K-S (Sig.)	.353	.557	.262	.259	.137
Intermediate-level RGs (n=38)	Mean±SD	14.71±14.31	13.84±10.88	11.54±11.16	12.30±10.82	10.53±10.45
	Min–Max	1.54 – 70.73	1.71 – 40.66	2.36 – 51.81	1.95 – 44.41	0.0 – 50.0
	K-S (Sig.)	.155	.303	.040*	.080	.236
Beginners (n=22)	Mean±SD	7.06±9.72	5.36±5.75	6.77±4.35	10.17±11.76	7.23±7.61
	Min–Max	1.17 – 47.69	1.19 – 25.24	1.48 – 15.84	1.29 – 44.15	0.0 – 23.0
	K-S (Sig.)	.077	.179	.576	.040*	.124
Total sample (N=126)	Mean±SD	15.45±13.83	14.84±12.77	9.95±8.67	11.91±10.75	14.80±15.01
	Min–Max	1.17 – 70.73	1.19 – 60.38	1.48 – 51.81	1.29 – 46.86	0.0 – 70.0
	K-S (Sig.)	.007*	.008*	.000*	.000*	.000*

Legend: n, N – number of study participants, RGs – rhythmic gymnasts, Mean – average value, SD – standard deviation, Min – minimum, Max – maximum, K-S – Kolmogorov-Smirnov test, Sig. – significance, L – left leg, R – right leg, BTOE – balance on toes, B1LEG – single leg balance, 2TUR – double turn in *passé*.

Note: All measures are in times, i.e. number of consecutive successful attempts (the third test).

\*Absence of normal distribution ( $p < 0.05$ )

Table 3. Intercorrelation matrix of all predictor variables and criterion variable: Total sample (N=126)

Variables	BTOE-L	BTOE-R	B1LEG-L	B1LEG-R	2TUR	FINS
BTOE-L	1.00					
BTOE-R	0.72**	1.00				
B1LEG-L	0.36**	0.34**	1.00			
B1LEG-R	0.37**	0.44**	0.34**	1.00		
2TUR	0.31**	0.35**	0.35**	0.29**	1.00	
FINS	0.36**	0.42**	0.21*	0.23*	0.45**	1.00

Legend: BTOE-L – balance on toes (left leg), BTOE-R – balance on toes (right leg), B1LEG-L – single leg balance (left leg), B1LEG-R – single leg balance (right leg), 2TUR – double turn in *passé*, FINS – final score.

\*significant at  $p < 0.05$ , \*\*significant at  $p < 0.01$

The results of the multivariate regression analysis indicate a statistically significant influence of balance ability on success (FINS) in RG among advanced-level RGs [ $R=0.69$ ,  $R^2=0.48$ , Adjusted  $R^2=0.35$ ,  $F(5,20)=3.65$ ,  $p=0.02$ ], and in the entirety of the sample [ $R=0.52$ ,  $R^2=0.27$ , Adjusted  $R^2=0.24$ ,  $F(5,120)=8.82$ ,  $p=0.00$ ], where balance ability explained success in RG with 48% ( $R^2=0.48$ ) and 35% (Adjusted  $R^2=0.35$ ) in the advanced-level group (Table 4a), and with 27% ( $R^2=0.27$ ) and 24% (Adjusted  $R^2=0.24$ ) in relation



to the entire sample (Table 4b). Of all age categories, why is the statistically significant influence of balance ability on performance score in RG recorded only in the sub-sample of advanced-level RGs? A possible explanation may be that children between the ages of 11 and 13 are able to apply strategies that strongly resemble those used by adults to maintain a balanced position in static or dynamic conditions (Müller et al., 1992; Hatzitaki et al., 2002; Calavalle et al., 2008). On the other hand, this concerns a very specific age that is part of a non-linear maturation process, which differs for everyone and affects their ability to learn and master particular motor skills (Ricotti, 2011). In the case of seniors [F(5,9)=0.41, p=0.83] and juniors [F(5,19)=1.12, p=0.38], as well as intermediate-level RGs [F(5,32)=2.02, p=0.10] and beginners [F(5,16)=1.52, p=0.24], the statistically significant influence of balance ability on performance score in RG was not confirmed. This result can be explained by the fact that it is premature to expect an enviable level of balance ability in the youngest age categories, because it requires training experience associated with improved neuromuscular coordination, and greater joint strength and range of motion, which are mechanisms for balance improvement (di Cagno et al., 2014). On the other hand, although senior and junior RGs, who are older age categories, have training experience, there is no statistically significant influence of balance ability on performance scores. This does not imply that balance abilities are not a key predictor of RG success, but rather that there are other, more relevant characteristics that differentiate successful from less successful RGs in older age categories (Пуреновић-Ивановић, 2017).

Table 4. The influence of balance ability on performance score in RG

a) Advanced-level RGs (n=26)						
R= .69, R <sup>2</sup> = .48, Adjusted R <sup>2</sup> = .35, F(5,20)=3.65, p= .02						
Variables	r	Part r	b	Std.Err. of b	t(20)	p-value
BTOE-L	0.39	-0.03	-0.01	0.02	-0.14	0.89
BTOE-R	<b>0.56</b>	<b>0.55</b>	<b>0.06</b>	<b>0.02</b>	<b>290.53</b>	<b>0.01</b>
B1LEG-L	0.48	0.28	0.08	0.06	130.28	0.21
B1LEG-R	0.25	-0.25	-0.05	0.04	-113.94	0.27
2TUR	0.23	0.22	0.02	0.02	101.02	0.32
b) Total sample (N=126)						
R= .52, R <sup>2</sup> = .27, Adjusted R <sup>2</sup> = .24, F(5,120)=8.82, p= .00						
Variables	r	Part r	b	Std.Err. of b	t(20)	p-value
BTOE-L	0.31	0.04	0.01	0.01	0.39	0.69
BTOE-R	<b>0.36</b>	<b>0.21</b>	<b>0.03</b>	<b>0.02</b>	<b>228.88</b>	<b>0.02</b>
B1LEG-L	0.12	0.00	0.00	0.02	0.01	0.99
B1LEG-R	0.25	0.07	0.01	0.01	0.81	0.42
2TUR	<b>0.41</b>	<b>0.37</b>	<b>0.04</b>	<b>0.01</b>	<b>437.47</b>	<b>0.00</b>

Legend: n, N – number of study participants, R – multiple correlation coefficient, R<sup>2</sup> – coefficient of determination of multiple correlation, Adjusted R<sup>2</sup> – adjusted coefficient of determination of multiple correlation, F – F-test value, p – significance of multiple regression, r – correlation coefficient, Part r – coefficient of partial correlation, b – standardized regression coefficient, Std.Err. of b – standardized error of regression coefficient, t – vector of standardized regression coefficient, p-value – significance of beta coefficient, BTOE-L – balance on toes (left leg), BTOE-R – balance on toes (right leg), B1LEG-L – single leg balance (left leg), B1LEG-R – single leg balance (right leg), 2TUR – double turn in *passé*.

At the univariate level, regression analysis indicated a statistically significant, individual contribution of the BTOE-R variable to the prediction of success in RG in the advanced-level RGs ( $p=0.01$ ; Table 4a), and in relation to the entirety of the sample ( $p=0.02$ ; Table 4b), with a positive relationship between this predictor and the criterion variable ( $b=0.06$  and  $b=0.03$ , retrospectively). This outcome is not a surprise considering that most of the exercises in RG require an above-average ability to maintain balance on one leg (full foot or *relevé* position), while the other leg is in various demanding positions (Sobera & Rutkowska-Kucharska, 2019). The reason for the absence of a statistically significant individual contribution of the BTOE-L variable in a sample of advanced-level RGs containing RGs whose left leg is the dominant leg may lie in the consideration of the results of some studies (Shigaki et al., 2013; Frutuoso et al., 2016), which recorded a better stability of the non-dominant leg – the preferred limb is used for dynamic activities, thus reducing its role in balance control (in this particular case, the advanced-level RGs' left leg is used for maneuvering, and the right leg is used for stabilisation and balancing). Although the asymmetry of the RGs' lower limbs was not the subject of this research, and differences between the left and right sides were not examined, this result shows exactly how the preference of one side of the body causes bilateral differences, both functional and morphological (Frutuoso et al., 2016). In addition to the BTOE-R variable, a statistically significant individual contribution of the 2TUR variable to the prediction of performance score in RG was recorded in relation to the entirety of the sample ( $p=0.00$ ; Table 4b), with a positive relationship between this predictor and the criterion variable ( $b=0.04$ ). Of all applied tests, in relation to the entire sample of participants, only the B1LEG test did not show a statistically significant individual contribution to success in RG, and this is the single leg test which is performed with weight placed on the entire length of the foot and with eyes closed. Namely, due to the fact that the RG Code of Points (FIG, 2022) values balance difficulties performed on tip-toes more, it is in RGs' best interest that such balance difficulties prevail; also, vision does not play a significant role in balance maintaining when it comes to RG (Potgieter, 2007; Calavalle et al., 2008).

### CONCLUSION

The goal of this research was to determine the influence of balance ability on the performance scores of high-level female RGs of different age categories. Accordingly, we analysed a factor which has previously been shown to be a very important segment of RG, and which is essential for success in this sport. Firstly, the status of static and dynamic balance abilities of RGs of all age categories was established; secondly, the relationships of all predictor variables with each other, and with the criterion variable,

were examined; finally, the influence of balance ability on performance scores in this sports discipline was examined. Given that a statistically significant influence of this segment of motor skills on success in this sport was established (at the multivariate level for advanced-level RGs and the entire sample, and at the univariate level for static balance on the tip-toes of the right leg and for the dynamic balance test), the results of this research can help RG coaches to better understand and to properly direct the training processes in relation to the balance ability of RGs of different ages, which would certainly lead to the improvement of their sports results, i.e. performance scores. This type of profiling can generate a useful database against which talented groups may be compared, although the balance ability assessment of the growing and developing individual is fraught with difficulties because of a range of issues. Unfortunately, given the fact that the results obtained from one specific age category cannot be generalised to apply to all age categories or skill levels, we can conclude that the results only apply to the specified age categories. Also, by carrying out a longitudinal research with a larger sample of examinees, we could gain even better insight into this segment of the motor status of RGs. Besides, this one-dimensional approach lacks the wider viewpoint necessary to account for the multidimensional nature of overall performance in RG.

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## СПОСОБНОСТ РАВНОТЕЖЕ ВРХУНСКИХ РИТМИЧКИХ ГИМНАСТИЧАРКИ: ДА ЛИ ПРЕДВИЂА РЕЗУЛТАТЕ ЊИХОВИХ ПЕРФОРМАНСИ?

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### Резиме

Ритмичка гимнастика (РГ) представља веома захтевну естетско-уметничку спортску дисциплину када је реч о комплексности неопходних вештина. Ритмичка гимнастичарка има задатак да координира технику тела са техником рада једним од укупно пет РГ реквизита (лопта, обруч, вијача, трака и чуњеви), истовремено демонстрирајући екстремно изражену флексибилност свих делова тела, те одличан осећај за ритам, простор и време. То је дисциплина која намеће високе захтеве по питању величине тела, грађе и састава, али и моторике извођача, нарочито оних врхунских. Међутим, да би се уопште могло приступити усвајању РГ садржаја, неопходно је постојање одређеног минимума развијености свих мо-

торичких способности, међу којима су постурална контрола и способност стабилизовања тела током динамичних кретњи од виталног значаја. У овој спортској дисциплини, равнотеже припадају тежинама телом (поред скокова и окрета), и у сваком саставу, са или без реквизита, ритмичка гимнастичарка мора да покаже владање сложеним равнотежама као карактеристичном структурном групом. Заступљене су обе врсте равнотежа које се испољавају у извођењу таласа, плесних корака, елемената ротације (окрети и пивоти) или издржаја у високом успону на једној ноzi (најчешће на тзв. *relevé* – успон на полупрстима, ређе него на пуном стопалу), уз истовремени или додатни рад слободне ноге и осталих делова тела, синхронизовано са радом реквизитом. Основни циљ овог истраживања је да утврди значај, допринос и утицај способности равнотеже на успех у ритмичкој гимнастици. Сто двадесет шест ритмичких гимнастичарки, распоређених у пет узрастних категорија (15 сениорки, узраста 16 година и више; 25 јуниорки, узраста 14–16 година; 26 кадеткиња, узраста 12–14 година; 38 пионирки, узраста 9–12 година; и 22 млађе пионирке, узраста 7–9 година) добровољно је учествовало у истраживању. Утврђене су њихове основне карактеристике (узраст, телесна висина и маса, индекс телесне масе), као и статус способности равнотеже, и то тестом равнотеже на прстима (лева/десна нога), тестом равнотеже на једној ноzi (лева/десна нога) – затворене очи, и посматрањем дуплих окрета у *passé* позицији. Подаци су анализирани (дескриптивна статистика, тест Колмогоров-Смирнов, мултиваријантна и униваријантна регресиона анализа) применом програма SPSS 21.0. Резултати мултиваријантне регресионе анализе указали су на постојање статистички значајног утицаја способности равнотеже кадеткиња, као и укупног узорка ритмичких гимнастичарки на успех у РГ ( $p=0.02$  и  $p=0.00$ , редом), са објашњењем варијансе од 35% (код кадеткиња), одн. 24% (на укупном узорку), при чему су утврђени статистички значајни појединачни доприноси успеху у РГ код равнотеже на прстима на десној ноzi (кадеткиње:  $p=0.01$ , укупан узорак:  $p=0.02$ ) и код динамичке равнотеже (укупан узорак:  $p=0.00$ ). Код сениорки и јуниорки, као и пионирки и млађих пионирки, није утврђен статистички значајан утицај способности равнотеже на успех у РГ. Овакав резултат се може објаснити чињеницом да је код најмлађих узрастних категорија још рано говорити о завидном нивоу ове моторичке способности, јер је за то неопходно тренажно искуство које са собом носи побољшану нервно-мишићну координацију, те већу снагу зглобова и обим покрета, који представљају механизме за побољшање способности равнотеже. Са друге стране, ту су старије узрастне категорије – сениорке и јуниорке, којима не мањка тренажно искуство, а опет изостаје статистички значајан утицај способности равнотеже на успех у РГ. То не значи да способност равнотеже није значајан фактор успеха у РГ, већ пре указује на постојање битнијих фактора који дискриминишу успешне од мање успешних ритмичких гимнастичарки у старијим такмичарским категоријама.