

## COMPARATIVE KINEMATICS ANALYSIS OF DIFFERENT SPLIT FRONT LEAPS

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### Abstract

*Introduction: The rhythmic gymnastics (RG) is a high leap demanding sport (Hutchinson et al., 1998). Leaps are fundamental human movements that require complex motor coordination of both upper and lower body segment. To make it all more interesting and complex, RG leaps performance is almost always followed by a requisite manipulation (the ball, the rope, the hoop, the ribbon, the clubs), and that manipulation is referred to requisite throws or passing through it. In spite of the growing popularity of this Olympic sport, there is a lack of biomechanical analyses in literature, regarding the techniques of rhythmic gymnastics. Aim: The aim of this study was to determine the difference in the certain kinematics parameters, between two types of the leaps, i.e., the front split leap, with the trunk bended backward, and both legs implied in the take off, after the stationary position and front split leap, with the trunk bended backward, and one leg implied in the take off, after the running, which could have an impact on the retention of well-defined "split" form. Method: The study included one subject - Evgenia Olegovna Kanaeva, Russian rhythmic gymnast, actual world champion, the only one in the history of the rhythmic gymnastics, who managed to win six gold medals at the World Championship. The sample of variables consisted of the following kinematics parameters in both types of the leaps: trajectory of the center of gravity of the body (CG) in X and Y axis and the resultant velocity ( $V_r$ ) of the CG. The data were obtained in the digitizing process, by using the software for kinematics analysis (Hum-an™, Version 5.0, 2005 HMA Technology Inc., Canada). The basic descriptive parameters and statistical significance of differences were determined by using the SPSS 12.0, statistical program for data processing. Results: The absolute frequencies in the  $V_r$  of the CG, showed the normal distribution in absolute values of the  $V_r$ , in the split front leap, with the trunk bended backward, and one leg implied in the take off, after the running. T-test showed that there was no statistically significant difference ( $p=.186$ ) in arithmetic mean values in the  $V_r$  of the CG, between both leaps, but a statistically significant correlation in the  $V_r$  of the CG in the flight phase was determined, in both split leaps ( $r=.658$ ,  $p=.002$ ). Conclusion: The split front leap, with the trunk bended backward, and both legs implied in the take off, after the stationary position, because of its mentioned characteristics, can be considered as energy demanding and more risky for injuries, due to the excessive velocity at the moment of the landing, and with justified greater difficulty in relation to the split front leap, with the trunk bended backward, and one leg implied in the take off, after the stationary position (0.1 point more).*

**Key words:** rhythmic gymnastics, kinematics analysis, front leaps, comparison

### Introduction

The rhythmic gymnastics (RG) is a high leap demanding sport (Hutchinson et al., 1998). Leaps are fundamental human movements that require complex motor coordination of both upper and lower body segment (Ashby & Heegaard, 2002). To make it all more interesting and complex, RG leaps performance is almost always followed by a requisite manipulation (the ball, the rope, the hoop, the ribbon, the clubs), and that manipulation is referred to requisite throws or passing through it. Above the requisites, arm swing plays important role, which was reported in certain studies, at least when speaking about vertical jump (Ashby & Heegaard, 2002). Doubtlessly, the rhythm is also important for the harmonious execution of various complex movements (Horvatin-Fučkar, 2005). In spite of the growing popularity of this Olympic sport, there is a lack of biomechanical analyses in literature, regarding the techniques of rhythmic gymnastics (Cicchella, 2009). Nevertheless, the most part of RG coaches have a great difficulty to analyze the most common errors in the leaps execution (Sousa & Lebre, n.d.).

That is essential, because during the flight phase gymnasts perform various technical figures, which are evaluated depending on weight level (Federation Internationale de Gymnastique, n.d.). The FIG point's code defines many different jumps, but the most preferred is the split leap. A proper leap refers to elements of body movements in certain dynamic poses in the unsupported position (the flight), after the takeoff from one or both legs]. There is a difference between jumps and leaps from one or both legs. The takeoff power (mainly upward) is directed by the leaps, therefore more often, a gymnast performs the take off with both legs. That is why; the body flight trajectory is steep. However, gymnasts usually choose to leap by taking off from one leg and swinging with the other leg, and in such leaps, the body flight trajectories are much more curved (Jastrjambaskaia & Titov, 1998). RG leaps have three phases: the preparatory (the takeoff), the main (the flight) and the finishing (the landing). The distribution of the gymnast's attention during each phase of jumping and leaping is not equal.

The attention is higher during the approach and the flight and lower during the takeoff and the landing]. This is because a better preparatory phase helps the gymnast in better control of her movements during flight. She usually takes off and lands automatically, without a great agitation (Jastrjambaskaia & Titov, 1998). The preparatory phase is actually divided into two parts: the preliminary subphase and the takeoff subphase. The preliminary subphase begins with a semisquat before the takeoff. To increase the height of the leap, the gymnast can use a vertical jump before the semisquat. During the semisquat, the gymnast should press her heel very fast into the floor (in an elastic manner), in order to quickly transfer her body weight. The body weight transfer through the heel, during the takeoff produces high elevation. Also, in the preparatory phase, various dance steps can be used (such as the gallop or the polka), the running, and the vertical jumps. Assuredly, the approach velocity influences the power of the takeoff. In RG, the best approach is of average intensity. In any case, the gymnast finishes the preliminary subphase with a semisquat, during which the muscles are spread, and ready for active contraction in the takeoff subphase. Certainly, the semisquat is very important. Indeed, the height of the jump or the leap depends on the depth of the semisquat. By increasing the depth of the semisquat, up to the optimal value, gymnast increases the height of the jump or the leap, although excess semisquat decreases the resulting height. The most important factor in semisquat depth is the angle of the knee articulations – the optimal semisquat depth is  $112^{\circ}$  (variations  $\pm 20^{\circ}$  reduce the resulting height). Semisquat depth also depends on the strength of the leg flexor muscles. The takeoff subphase gives to the gymnast's center of gravity a vertical speed. As the speed is greater, it causes a greater the flight's height. The takeoff begins with a change in the angle of the hip articulations, followed by knees, and finally ankles.

The foot leaves the floor, starting with the heel and finishing with the tips of the toes. At this very moment, the gymnast has to straighten her legs and stretch her toes. It's necessary to focus the efforts on the foot, because strong foot muscles, help create strong takeoffs. Thus, the jump's height depends on the strength and elasticity of the leg muscles, the foot, the knee ligaments, and the Achilles tendon. A great leap requires a precise, strong and quick takeoff in the right direction. The efficiency of the leap depends on the leg and the arm coordinating movements. In fact, the arms are the "wings", which help gymnast in increasing the effectiveness of the takeoff (more demanding leap, needs stronger arm swing). Moreover, the trunk position is very important and high demanding leaps require tightened back muscles, especially in the lower back (Jastrjambaskaia & Titov, 1998). RG encompasses two main kinds of the takeoff: the takeoff from two legs and the takeoff from one leg, while swinging the other. The flight phase: As mentioned, duration and the height of the flight are mainly determined by the takeoff subphase.

However, the shape of the leap, also affects the height. The flight duration of high leaps is close to 0.5 s. By knowing the time of the flight, it is possible to calculate the increase in the height of the gymnast's center of gravity:

$$H = \frac{1}{2} \cdot g \cdot t^2,$$

where H is the height of elevation (in meters), g is the acceleration due to the gravity (in  $m/s^2$ ), and t is the time taken to rise (in seconds). As can be seen from the formula, a large flight height results from a lengthy duration of the rising. That, in turn, results in a greater flight time and a correspondingly greater opportunity for the gymnast to establish wanted pose during the flight. During this phase, a gymnast reaches a necessary shape at first, and then prepares for landing. Duration of the shape depends on the duration of the flight and the time taken to reach the pose. The less time is lost in reaching the pose, there is a more time for demonstrating this shape in the flight, which is the thing evaluated by judges. The time taken to reach the pose can only be reduced by increasing the velocity of the center of the gravity at the takeoff (Jastrjambaskaia & Titov, 1998).

The finishing (the landing) phase: The purpose of this leap's phase is to decrease the speed of the gymnast's movements. Stability during the landing depends upon the trajectory of the gymnast's body during the flight, and also the gymnast's ability to correct an inaccurate landing with her arms, head and trunk movements, and by using her leg muscles strength. Of course, poor landing technique and hard floors increase the load on the gymnast's musculoskeletal system. The gymnast should achieve the soft and the silent landing by rolling from her toes to her heels, and by gently bending in knee articulations, followed by quick straightening in knee articulations. In this way, a good landing reduces the negative acceleration arising at the moment of floor contact and eases the abrupt impact. It is easier to land on the both legs in a semisquat than to land on the single leg. It comes as no surprise, the fact that the landing phase represents the greatest risk of injury in the leap (it is thought that 34% of all gymnasts' injuries occur during the landing). That's why it is necessary to teach gymnasts to pay attention to the sounds of the landing (heavy landing indicates poor absorption of the force, made in the impact moment between the foot and the floor). There are several methods for classifying the jumps and the leaps in the RG, and the most common are based on describing the takeoff and the landing, and on analyzing the pose during the flight phase. The rhythmic gymnasts use most commonly one of three poses during the flight: the split position, the ring position and the stag position. The split position requires the following (Jastrjambaskaia & Titov, 1998): legs are apart and aligned with each other; the legs are horizontal to the floor, legs are straightened in the knee articulations; the fixed-split position during flight, allowing clear evaluation of the split position; the vertical trunk position. The front split leap is the main leap in the split group.

This leap implies the one leg take off and the swinging with another leg, while moving up and forward. During the flight, a gymnast demonstrates the split pose and reaches the horizontal position. During the takeoff, her trunk is slightly inclined forward, but straight during the flight, but there are also variations (the trunk bended backward). Gymnast lands on her swinging leg. This leap may also be performed by taking off from both legs. Within each group of the leaps, the difficulty is determined by the body element, and in order to be recognized, the difficulty has to be performed, conjointly, with requisite's element of mastership (with or without ejection of the requisite) and without technical errors. There are following levels of the difficulty: A=0.10, B=0.20, C=0.30, D=0.40, E=0.50, F=0.60, G=0.70, H=0.80, I=0.90, J=1.00 or more (Federation Internationale de Gymnastique, n.d.).

All the difficulties should have the following characteristics: the sufficient height, i.e., the elevation (necessary in the flight phase, to achieve and keep, well defined form of the leap); kept and well defined form during the flight; well amplitude; requisite's element of mastership. In order to gymnast in the competition perform all the provided elements in the best way, it is necessary that, at least 60 minutes before the competition, dedicate to the warm up, i.e., the slow running, the rhythmic steps and the leaps (Guidetti et al., 2009). This research represents the analyses of the front split leap, with the trunk bended backward, and both legs implied in the take off, after the stationary position (G difficulty - 0.70), as well as the front split leap, with the trunk bended backward, and one leg implied in the take off, after the running (F difficulty - 0.60). The data were obtained by using the kinematics method (Bubanj, S. et al., 2009). The leaps were performed by the actual World Champion Evgenia Kanaeva (RUS), during the 29-th World Championship in Japan, 2009, in the exercise with the rope. The subject of the research is a detailed analysis of two different split leaps, which differ in the preparation for the leap, the way of the takeoff, and in handling with the requisite - the rope (presence or absence of the arms' swing). The aim of this study was to determine the difference in the certain kinematics parameters, between two mentioned types of the leaps, which could have an impact on the retention of well-defined "split" form.

## Methods

The study included one subject - Evgenia Olegovna Kanaeva, Russian rhythmic gymnast (born 02.04.1990., body weight 42 kg and body height 168 cm), actual world champion, the only one in the history of the rhythmic gymnastics, who managed to win six gold medals at the World Championship. She is considered, as the best rhythmic gymnasts in the history (Wikipedia the Free Encyclopedia, n.d.). Video recordings of the actual champion performing the leaps were downloaded from the Internet (YouTube, 2009).

The sample of variables consisted of the following kinematics parameters in both types of the leaps: trajectory of the center of gravity of the body (CG) in X and Y axis and the resultant velocity ( $V_r$ ) of the CG. The data were obtained in the digitizing process, by using the software for kinematics analysis (Hu-m-an™, Version 5.0, 2005 HMA Technology Inc., Canada). Scale, necessary for the digitizing process was determined by the knowledge of the subject's body height. The basic descriptive parameters and statistical significance of differences were determined by using the SPSS 12.0, statistical program for data processing.

## Results

The split front leap, with the trunk bended backward, and both legs implied in the take off, after the stationary position (G difficulty - 0.70), is characterized by (in this specific case), arms swing (the extension in the shoulder articulations up to 180°), with dropping of one end of the rope. The leap had three phases: the takeoff (Fig. 1), the flight (Fig. 2) and the landing (Fig 3). From the moment of the takeoff up to the landing, elapsed time was 0.57s, i.e. video record was divided in to 36 frames (null + 35), which means that between two adjacent frames elapsed 0.016s.



Figure 1. The moment of the takeoff (6. frame) and also, the first peak of the resultant velocity of the CG.



Figure 2. The moment of retention of the form (16. frame).

Graph 1, shows the trajectory of the CG in X and Y axes. There is a plateau in vertical direction of gymnast's CG, from 12. to 14. frame, in duration of 0.048s (from 0.21s to 0.24s). There are two peaks in the resultant velocity of the split front leap, with the trunk bended backward, and both legs implied in the take off (Graph 2).

The first peak occurred in the 6. frame – in the moment of the takeoff, with the velocity of 2.7 m/s, while the second peak occurred in the 24. frame – in the moment of the landing, with the velocity of 3.1 m/s.



Figure 3. The moment of landing and also, the second peak of the resultant velocity (24. frame).

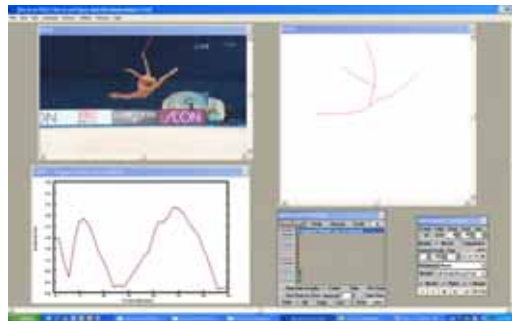
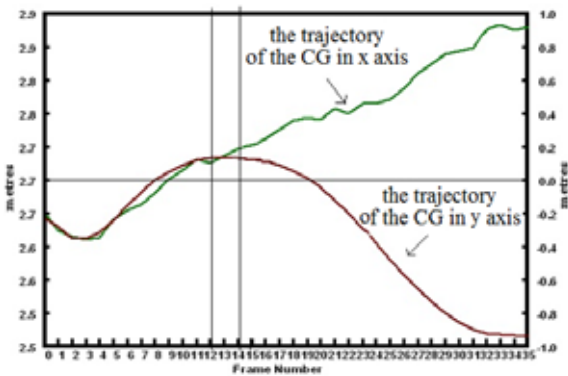
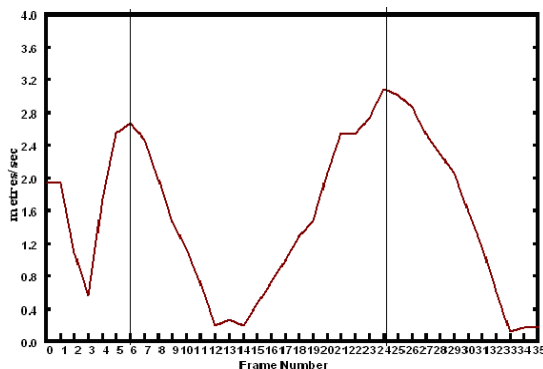


Figure 4. The split leap with both legs implied in the takeoff, after the digitalization.



Graph 1. Trajectory of the CG in X and Y axes.



Graph 2. The first and the second peak in the Vr of CG (6. and 24. frame, respectively).



Figure 5. The moment of the takeoff (10. frame) and also, the first peak of the resultant velocity of the CG.



Figure 6. The moment of retention of the form (21. frame).



Figure 7. The moment of landing and also, the second peak of the resultant velocity (25. frame).

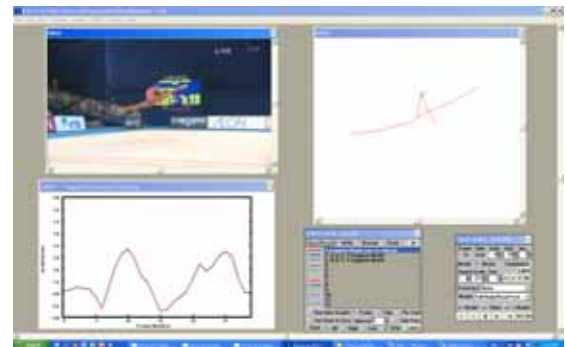


Figure 8. The split leap with one leg implied in the takeoff, after the digitalization.

Table 1 shows the values of the Vr, during the split front leap, with the trunk bended backward, and both legs implied in the take off.

Table 1. The values of the Vr.

Frame №	Vr (m/s)		Frame №	Vr (m/s)	
0	1.931645	The preparation for the leap	18	1.294273	The flight
1	1.931645		19	1.479225	
2	1.080239		20	2.060119	
3	0.568849		21	2.546657	
4	1.750705		22	2.528262	
5	2.549806		23	2.740603	
6	2.677057	The moment of the takeoff	24	3.088257	The moment of the landing
7	2.464588	The flight	25	3.016689	The phase of the landing
8	1.991826		26	2.865460	
9	1.462125		27	2.534489	
10	1.140194		28	2.290953	
11	0.712612		29	2.065069	
12	0.197419		30	1.590917	
13	0.196226		31	1.163819	
14	0.195828		32	0.610709	
15	0.467675		33	0.122928	
16	0.733103	The form	34	0.170085	
17	0.996092		35	0.170085	

Table 2. The values of the Vr of the CG.

Frame №	Vr (m/s)		Frame №	Vr (m/s)	
0	0.901332	The preparation for the leap	15	0.227537	The flight
1	0.901332		16	0.241624	
2	1.019661		17	0.521225	
3	0.956211		18	0.665130	
4	0.961941		19	0.878769	
5	0.706121		20	1.304916	
6	0.321777		21	1.781962	The form
7	0.981252		22	1.539379	The flight
8	1.660209		23	1.694525	
9	2.111369		24	2.036984	
10	2.275251	The moment of the takeoff	25	2.198236	The phase of the landing
11	1.945712		26	2.022314	The phase of the landing
12	1.387216		27	1.290518	
13	1.189276		28	0.815545	
14	0.675492		29	0.815545	

Table 3. Duration of the flight phase and values of the Vr of the CG, in both type of the leaps, from the moment of the takeoff to the moment of the landing.

Frame №	The beginning	The resultant velocity of the split leap from	The resultant velocity of the split	The beginning	Frame
6	0.11	2.677057 <sup>1</sup>	2.275251 <sup>1</sup>	0.18	10
7		2.464588	1.945712		11
8		1.991826	1.387216		12
9		1.462125	1.189276		13
10		1.140194	0.675492		14
11		0.712612	0.227537		15
12		0.197419	0.241624		16
13		0.196226	0.521225		17
14		0.195828	0.66513		18
15		0.467675	0.878769		19
16	0.27	0.733103 <sup>2</sup>	1.304916		20
17		0.996092	1.781962 <sup>2</sup>	0.35	21
18		1.294273	1.539379		22
19		1.479225	1.694525		23
20		2.060119	2.036984		24
21		2.546657	2.198236 <sup>3</sup>	0.42	25
22		2.528262	2.022314		
23		2.740603	1.290518		
24	0.4	3.088257 <sup>3</sup>	0.815545		

<sup>1</sup> - the moment of the takeoff, <sup>2</sup> - the moment of retention of the form, <sup>3</sup> - the moment of the landing

Table 4. Descriptive parameters of the Vr from the moment of the takeoff to the moment of the landing in both types of the leaps.

Vr (m/s)	The split leap from the stationary position	The split leap from running
N (frame)	19	19
Mean ± SD	1.529 ± 0.963	1.299 ± 0.658
Min	0.20	0.23
Max	3.09	2.28

Table 5. The sign. of difference in the Vr of the CG, between the split front leap, with both legs implied in the take off, after the stat. pos., and the split front leap, with one leg implied in the take off, after the running.

The split leaps		Paired Differences					t	df	Sig.
		Mean	SD	S.E.M.	95% Confidence				
					Lower	Upper			
Pair 1	from the stationary - from the running	.229	0.726	0.1665	-.12072	.57877	1.376	18	.186

Table 6. The correlation significance in the Vr of the CG in the flight phase in both split leaps.

Pair 1		N	Correlation	Sig.
Pair 1	from the stationary - from the running	19	.658	.002

In the moment of the takeoff (frame 6), gymnast's CG was moving at the velocity of 2.68 m/s; in the moment of retention of the form (frame 16), the CG was moving at the velocity of 0.73 m/s; in the moment of the landing (frame 24), the CG was moving at top velocity (3.09 m/s). The split front leap, with the trunk bended backward, and one leg implied in the take off, after the running (F difficulty – 0.60), is characterized by (in this specific case), arms swing (full circle in the sagittal plane) and passing through the rope, with backward rotation. The leap had three phases: the takeoff (Fig. 5), the flight (Fig. 6) and the landing (Fig 7). From the moment of the takeoff up to the landing, elapsed time was 0.46s, i.e. video record was divided in to 29 frames (null + 28), which means that between two adjacent frames elapsed 0.016s. Graph 3, shows the trajectory of the CG in X and Y axes. There is a plateau in vertical direction of gymnast's CG, from 15. to 16. frame, in duration of 0.032s (from 0.26s to 0.27s). There are two peaks in the resultant velocity of the split front leap, with the trunk bended backward, and one leg implied in the take off (Graph 4). The first peak occurred in the 10. frame – in the moment of the takeoff, with the velocity of 2.3 m/s, while the second peak occurred in the 25. frame – in the moment of the landing, with the velocity of 2.2 m/s. The Table 2 shows the values of the Vr, during the split front leap, with the trunk bended backward, and one leg implied in the take off. In the moment of the takeoff (frame 10), gymnast's CG was moving at top velocity of 2.28 m/s; in the moment of retention of the form (frame 21), the CG was moving at the velocity of 1.78 m/s; in the moment of the landing (frame 25), the CG was moving at the velocity of 2.19 m/s. In order to test the difference in the Vr of the CG in two split leaps with different preparatory and takeoff subphases, it is necessary at first, to equal these jumps. Namely, both leaps have identical flight phase (the period from the takeoff by the time of impact with the ground), if we exclude the different arms swing, as well as various manipulation with the rope. In this way, the comparison of the leaps, from the moment of the identical flight phase is allowed. Table 3 shows the absolute values of the velocity of the CG, from the moment of the takeoff, up to the landing, as well as the duration of the phases of flight, after their equalization. Table 4 shows the basic descriptive parameters in the Vr of the CG, during the flight phase, in both split leaps.

There is a greater average resultant velocity of the gymnast's CG in the split leap from the stationary position. There is almost no difference in the minimum velocity values in both leaps, while a greater value in the maximum velocity was achieved in the split leap from the stationary position. Absolute frequencies in the Vr of the CG are shown in the histograms 1 and 2, where the normal distribution in absolute values of the Vr is obvious in the split front leap, with the trunk bended backward, and one leg implied in the take off, after the running. T-test (Table 5) showed that there was no statistically significant difference ( $p=.186$ ) in arithmetic mean values in the Vr of the CG, between both leaps, but a statistically significant correlation (Table 6) in the Vr of the CG in the flight phase was determined, in both split leaps ( $r=.658$ ,  $p=.002$ ).

### Discussion and conclusion

Kinematics of analyzed split leaps in the RG was presented on the basis of the results of one subject, the top rhythmic gymnast. Two split leaps, different in the preparation and takeoff phase and in arms swing during the flight phase, were described and compared. Kinematics analysis showed notably, normal distribution in absolute values of the Vr in the split front leap, with the trunk bended backward, and one leg implied in the take off, after the running, but greater individual values of the Vr in the split front leap, with the trunk bended backward, and both legs implied in the takeoff, after the stationary position.

Also, in the first mentioned leap, the flight phase lasted longer; the desired form was obtained earlier, and was sustained longer in relation to the time (which is one of the requirements for the recognition of the leap's difficulty). At the end of the twentieth century, the authors from Portugal (Sousa & Lebre, n.d.), analyzed biomechanically, the split front leap, with and without the trunk bended backward, in the top 12 rhythmic gymnasts, aged  $15\pm 3.2$  years (Mean $\pm$ St.dev.), body weight  $49.4\pm 4.7$  kg (Mean $\pm$ St.dev.) and body height  $167.2\pm 6.8$  cm (Mean $\pm$ St.dev.). The leaps were analyzed by using the Peak 5 - Motion Measurements System. The results showed significantly greater value of the average velocity of the CG, at the moment of the takeoff, but similar values of the velocity at the moment of the landing.

The authors, among other, concluded that the leap without the trunk bended backward, as simpler, showed lesser achieved values, because the gymnasts were less concentrated and invest less effort, when performing simple and less demanding leaps. Author Cicchella (2009), carried out the kinematics analysis of four leaps in the RG and among others of split front leap, without the trunk bended backward, in the national champions of average age 16 years, body weight 50 kg and body height 173 cm. The leaps were recorded and analyzed by using automated analytical system of movement with six cameras (Vicon 460, Oxford Metrics, UK). The obtained research results showed, the longer duration of the flight phase (0.77 s), compared to the values obtained in this our (0.57 s), although the leap was less difficult. In the study of Di Cagno et al. (2009), the authors compared 24 gymnastics (12 men and 12 women, aged  $22 \pm 4$  years, Mean $\pm$ St. Dev.), while performing the three different technical leaps: 1) split leap with legs spread; 2) Kozak with the rotation of  $180^\circ$ ; 3) Jeté with turn. The gymnasts of the masculine sex, compared to the gymnasts of the feminine sex, had a greater height of the leaps (plateau) and greater contact duration of the takeoff leg with the ground, but in the elastic properties of the muscles, between the sexes, there was no difference. In conclusion, the authors noted that in the gymnastics selection process, coaches should focus on the neuromuscular parameters and elastic properties of the leg muscles, in future gymnastics. In their earlier research, mentioned authors di Cagna et al. (2008), attempted to establish the determinant parameters of success, between 25 gymnasts (top and those with less success), which involved the anthropometric characteristics, three types of the vertical jumps and three types of the technical split leaps.

In conclusion, authors noted a statistically significant difference ( $p < 0.05$ ) in the body height ( $1.65 \pm 0.03$ m vs.  $1.55 \pm 0.09$ m, Mean $\pm$ St. Dev.) and the body weight ( $42.42 \pm 0.03$ kg vs  $35.84 \pm 5.66$ kg, Mean $\pm$ St.Dev.) and in the technical split leaps, in favor of the top gymnasts, whereas in the vertical jumps, there was no significant difference between the groups. In the research of Dyhre-Paulsen (1987), the author found that the subjective assessment of experienced judges, who assesses the skills in the split leap of the gymnastics, positively correlated with minimal flexion in the knee articulation, during the landing phase.

Maximum flexion in the knee articulation, on the contrary, negatively correlated with grade ( $p < 0.0002$ ). It was also found, in more talented gymnastics, compared to the less talented, an earlier contraction of muscles tibialis anterior and gastrocnemius, with shorter periods of activities and longer breaks between the activities. The split front leap, with the trunk bended backward, and both legs implied in the take off, after the stationary position, because of its mentioned characteristics, can be considered as energy demanding and more risky for injuries, due to the excessive velocity at the moment of the landing, and with justified greater difficulty in relation to the split front leap, with the trunk bended backward, and one leg implied in the take off, after the stationary position (0.1 point more). The current results were obtained by using only kinematical method, and in the terms of the top competition. The comprehensive analysis requires a multidisciplinary approach, which would involve the application of the electromiographical method, the tensiometric platform and the laboratory conditions.

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## KOMPARATIVNA KINEMATIČKA ANALIZA DALEKOVISOKOG SKOKA KROZ OTVORENU VIJAČU

### Sažetak

*Uvod: Ritmička gimnastika (RG) je sport sa visokim zahtjevima u skokovima. Skokovi spadaju u fundamentalne čovjekove kretnje, koje zahtijevaju složenu koordinaciju i gornjih i donjih segmenata tijela. Da sve bude zanimljivije i kompleksnije, skokovi u RG se gotovo uvijek izvode uz manipulaciju nekim od rekvizita (lopta, vijača, obruč, traka, čunjevi), a ta manipulacija podrazumijeva izbacivanje ili prolazak kroz rekvizit. I pored sve veće popularnosti ovog Olimpijskog sporta, osjeća se nedostatak biomehaničkih analiza u literaturi u pogledu tehničkih elemenata. Cilj: Cilj istraživanja bio utvrđivanje razlika u pojedinim kinematičkim parametrima dvije vrste dalekovisokih skokova, koje mogu imati utjecaj na zadržavanje dobro definiranog „split“ oblika. Metode: Istraživanjem je obuhvaćena jedna ispitanica - Evgenija Olegovna Kanaeva, ruska ritmička gimnastičarka, aktualna svjetska prvakinja, jedina kojoj je u povijesti ritmičke gimnastike pošlo za rukom da osvoji šest zlatnih medalja na Svjetskom prvenstvu. Uzorak varijabli je podrazumijevao slijedeće kinematičke parametre kod obje vrste skoka: trajektorija težišta tijela po X i Y osi i rezultatna brzina kretanja težišta tijela (TT). Podaci su dobiveni postupkom digitalizacije, pomoću softvera za kinematičku analizu Hu-m-an™, Version 5.0. Osnovni deskriptivni parametri i statistička značajnost razlika utvrđeni su pomoću SPSS 12.0, statističkog programa za obradu podataka. Rezultati: Analizom apsolutnih učestanosti rezultatne brzine TT, uočava se normalnija distribucija apsolutnih vrijednosti brzine kod jednonožnog dalekovisokog skoka iz zaleta. T-test je pokazao da ne postoje statistički značajne razlike ( $p=.186$ ) aritmetičkih sredina vrijednosti brzine kretanja težišta tijela kod dalekovisokog skoka iz mjesta sunožnim odrazom i iz zaleta jednonožnim odrazom, ali je utvrđeno da postoji statistički značajna korelacija brzine u fazi leta jednog i drugog skoka ( $r=.658$ ,  $p=.002$ ). Zaključak: Skok sunožnim odrazom se zbog navedenih karakteristika može smatrati energetski zahtjevnijim i rizičnijim za povrede zbog prevelike brzine u trenutku doskoka i opravdano veće težine u odnosu na skok jednonožnim odrazom (0.1 bod više).*

**Ključne riječi:** ritmička gimnastika, kinematička analiza, skok kroz vijaču, usporedba

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