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Original Article

Biomechanical analysis of the phase structure of Pak Salto on uneven bars

VALERIAN NICOLAE FORMINTE[1], LILIANA COSMA[2], MIRELA DAMIAN[3], TATIANA DOBRESCU[4], VLADIMIR POTOP[5]
[1,3]Ovidius University of Constanta, ROMANIA
[2] "Cetate" Deva High School with Sports Program, ROMANIA
[4]Vasile Alecsandri University of Bacau, ROMANIA
[5]Department of Physical Education and Sport, University of Pitesti, ROMANIA

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Abstract
Purpose. The aim of the paper is to highlight the biomechanical characteristics of the phase structure in the transition from the high bar to the low bar with flight phase – Pak Salto. *Material.* The comparative biomechanical analysis was carried out during two international competitions, in 2017 and 2018. Seven female gymnasts (14-15 years old) on the uneven bars participated in this research. The comparative computerized video analysis of the phase structure of the transition from the high bar (HB) to the low bar (LB) –Pak Salto – was performed by means of Physics ToolKit program. The Kinovea program was also used to measure the segmental angular characteristics in each key position of the phase structure of Pak Salto execution technique. *Results.* The key components of the phase structure of the execution technique used for the transition from the HB to the LB with Pak Salto were identified by analyzing the segmental angular characteristics. The results of these angular characteristics of the key components revealed the values of the angle between hip-torso and torso-arms. In order to perform the video analysis, the biomechanical parameters were calculated. The results of the angular velocity in the phase of the preparatory movement indicate a decrease of the value before releasing the bar; in the basic movement phase, at the multiplication of the body posture (MP), the general center of mass (COM) shows an increase in the angular velocity at the toes. In the concluding body posture - final position 1 (CP1) – there is a decrease of the angular velocity of the toes and in CP2 – the angular velocity decreases in all segments. The force in the preparatory movement phase has higher values at the toes and COM. There is a decrease in the shoulders in SPh1 and an increase of the toes force value in SPh2-LP; in the phase of basic movement, at MP – an increase is noticed at the pointed toe; in the concluding body posture, at CP1.1 – there is a decrease in toes and arms; in CP1.2 – a decrease in all body segments. *Conclusion.* The biomechanical video analysis revealed the spatio-temporal characteristics of the COM trajectory, the value of the angular velocity in relation to the COM and the resultant of the force during the execution of the transition from the HB to the LB with Pak Salto flight phase, according to the method of motion postural cues.
Key words: comparative analysis, key components of the technique, angular characteristics, spatio-temporal characteristics, angular velocity, force.

Introduction

The uneven bars –specific event in Women's Artistic Gymnastics – have a content enriched with new elements, whose names do not yet appear in the specialized literature. The particularities of the apparatus construction determined a specific technique and structure of the movements performed on the 2 bars, closely connected to the movements made on the horizontal bar in Men's Artistic Gymnastics. They offer the possibility to perform the most unusual and complex elements, made in various connections, with release and regrasping of bars, changes of grasps allowing to modify the body posture between the bars - above, below or outside them (Grosu, 2004, Forminte et al., 2019; Mustafa & Abdwahhab, 2020). Currently, the uneven bars have a new design, characterized by a larger distance between the pillars on which the bars are fixed (1.80 m). This fact allows the athlete to perform movements while in hanging position or in handstand: releases, mounts, rotations (giant circles), Stalder, turns in hanging position, support, movements near the bar. Also, as in a body position without support, it is possible to perform transitions from the low bar to the high bar (Shaposhnikova) and transitions from the high bar to the low bar - Pak Salto (in free flight: flights, dismounts) (Xin & Li, 2000; FIG, 2016; Petković, 2019; Kalinski, Kezić, & Jelaska, 2020).

The specialized literature underlines the fact that the analysis of execution technique and learning of these movements must take into consideration the knowledge of the technique components, but also the body posture or position in time and space. The technique of exercises in gymnastics was studied by means of the method of "motion postural cues", developed by V.N. Boloban, E.V. Biryuk (1979), methodologically improved and practically applied nowadays (Boloban & Potop, 2014; Biegajlo et al., 2022).

Corresponding Author: VLADIMIR POTOP, E-mail: vladimir_potop@yahoo.com

The biomechanical studies in artistic gymnastics can be carried out by using the biomechanical methods and also the methods taken over from other related knowledge sciences such as: pedagogical, physiological, psychological, medical, mechanical methods etc. (Potop & Cretu, 2018; Nyman, 2020).

Many of the important studies focused on the biomechanical analysis of the giant circles, as well as the Tkachev and Jaeger type flights or the releases with various degrees of difficulty (Čuk et al., 2009; Manning et al., 2011; Irwin et al., 2011; Irwin et al., 2014). At the present moment, the following research is of interest: biomechanical studies on the indicators of the transfer of giant circles technique elements, executed on high bar and uneven bars; studies on the basic technique; assessment of the different male and female anthropometric indicators, correlated with the results of the differences between velocity and movement amplitude; biomechanical analysis of the swings and tap swings etc. (Han & Kwon, 2007). At the same time, it was found out that the processing of the valid methods and means for learning the increasingly complex (basic) specific exercises, considering the individual indicators, is extremely slow. The absence of the studies related to the topic approached in this research was also noted, especially regarding the transition from the high bar to the low bar on uneven bars.

The purpose of the paper is to perform the biomechanical analysis meant to highlight the biomechanical characteristics of the phase structure of the transition from the high bar to the low bar with flight phase (Pak Salto).

Material and methods.

Participants

Seven gymnasts of 14-15 years old (mean ± SEM in weight of 41.66 ± 1.55 kg and a height of 1.74 ± 0.02 m), members of the national team, out of which two finalists in the uneven bars event, participated in this study. Their exercises on the uneven bars were monitored during two international competitions, in 2017 and 2018. These gymnasts were informed about the requirements and conditions of the test and they agreed to take part in the study.

Instruments and procedure

The research was based on the videos available on YouTube with 1080p (.mp4) full-HD resolution. In order to perform the video biomechanical analysis, it was necessary to convert the mp4 format into AVI (30 frames/sec) using the Pinnacle Studio program, version 21. The video comparative biomechanical analysis was carried out by means of Physics ToolKit program, using the postural cues method for the identification, measurement and evaluation of sports technique key elements in the Pak Salto, difficulty value D (0.4) on uneven bars (method of motion postural cues, Sadowski, Boloban, Niźnikowski et al., 2012; Boloban & Potop, 2014). The research used also the Kinovea program to measure the segmental angular characteristics in each key position of the phase structure of "Pak Salto" technique, namely: angle between hip and torso (a) and angle between torso and arms (b). In the preparatory movement phase, 1 – sub-phase (SPh1) – body posture at the horizontal of HB, 2 – sub-phase 2 – launching posture (SPh2-LP) – body posture before releasing the bar. Phase of basic movement, 3 – multiplication of body posture (MP) at the maximum height of the general center of mass (COM). Phase of final posture, 4 – concluding body posture (CP1.1), grasping the LB in the first contact with the bar – support and 5 –concluding body posture 2 (CP1.2) –continuation of the movement, preparation for the next element.

Statistical analysis

The statistical processing was made with the help of the KyPlot specialized program, version 5.0, KyensLab Inc. (Japan). In this regard, the usual descriptive indicators were used: mean, SEM - standard error of the mean, SD- standard deviation, Cv (%) – coefficient of variation; t -test at $p < 0.05$.

Results

Figure 1 shows the phase structure of the key elements in the execution technique of the transition from the high bar (HB) to the low bar (LB), with Pak Salto on UB, performed by the athlete Eremena, RUS – the first place on this apparatus at the World Artistic Gymnastics Championships – Individual events, Montréal (CAN), 2017, in the qualifying competition. By means of the Kinovea program, 5 key moments were identified in the phase structure of the salto.

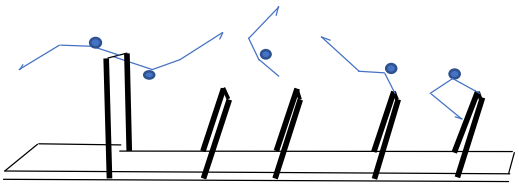


Figure 1. *Transition from the high bar (HB) to the low bar (LB) with flight phase –"Pak" Salto* (Eremina, RUS); Notes: 1 – sub-phase 1(SPh1); 2 – sub-phase 2 – launching body posture (SPh2- LP); 3 – multiplication of body posture – flight phase (MP); 4 –concluding body posture 1 (CP1); 5 – concluding body posture 2 (CP2)

Table no 1. *Angular characteristics of body segments during the transition from HB to LB with Pak Salto on the uneven bars* (n = 7)

Symbol/ statistical indicators	Preparatory movement (degrees)					Basic movement (degrees)		Concluding movement (degrees)			
	P.I.	1		2		3		4		5	
	a	a	b	a	b	a	b	a	b	a	b
I SPk#	SM	154	123	215	124	205	195	200	179	#	#
P_SPk	SM	159	103	197	104	217	184	171	145	133	111
D_SPk	L	158	150	171	114	215	201	195	123	183	86
G_SPk	L	122	157	181	155	235	227	226	161	210	94
S_SPk	L	137	181	164	127	230	189	222	151	209	66
Sf_SPk	SM	109	153	150	142	226	184	194	155	192	111
C_SPk	L	104	190	147	146	241	207	216	143	208	82
mean	-	**134.7**	**151**	**175**	**130.3**	**224.1**	**198.1**	**203.4**	**151**	**189.2**	**91.7**
SEM	-	8.83	11.49	9.34	6.90	4.73	5.79	7.29	6.52	12.1	7.16
*Kl SPk	L	152	165	211	105	231	153	226	132	206	75
*B SPk	L	156	134	157	127	197	185	193	146	192	100

Notes: # - failed execution (fall); SM – start from handstand; L – start from launching posture(swing); *champion athlete considered a model for performance; SPk – symbol of the" Pak Salto" element name; *Kl – Klimenko (RUS); *B – Biles (USA)

Table no. 1 shows the angular characteristics of the body segments in the transition from the HB to the LB with Pak Salto (n = 7), compared to 2017. The results of the comparative analysis, consistent with the key elements of the technique used in the phase structure of Pak salto, highlight the value of the angle between hip-torso (a) and the angle between torso - arms (b). The *preparatory movement phase*, 1 - SPh1 – body posture at the horizontal of HB, the angle (a) increased by 24.7° (110°) and the angle (b) decreased by 9.5° (160.5°); 2 – SPh2-LP – body posture before releasing the bar, the angle (a) increased by 9.8° (165.2°) and the angle (b) decreased by 20.9° (151.2°).

The *basic movement phase*, 3 – MP – multiplication of body posture at the maximum height of the general center of mass (COM), the angle (a) decreased by 18.6° (242.7°) and the angle (b) increased by 9.9° (188,2°). The *concluding movement phase*, 4 – CP1.1 – concluding body posture 1- grasp of LB – the first contact with the bar – support, angle (a) increased by 28.2° (175.2°) and angle (b) increased by 25.8° (125.2°); in 5 – CP1.2 – concluding posture 2 of movement continuation – preparation for the next element, angle (a) increases by 85.7° (103.5°) and angle (b) decreases by 20.5° (112.2°).

Table no. 2 presents the anthropometric and biomechanical parameters necessary for the biomechanical study of the transition from the high bar to the low one–Pak Salto on the uneven bars.

Table no 2. *Biomechanical parameters needed for the transition from HB to LB–Pak Salto on the uneven bars* (n = 7)

Symbol/ statistical indicators	IR (kg·m^2)	Radius of segmental movement (m)			
		Toes	COM	Shoulders	Arms
I_SPk#	149.42	1.562	0.970	0.678	0.419
P_SPk	135.04	1.496	0.985	0.825	0.636
D_SPk	93.89	1.569	0.962	0.745	0.499
G_SPk	129.7	1.571	1.040	0.855	0.723
S_SPk	113.7	1.655	1.019	0.747	0.514
Sf_SPk	125.46	1.470	0.929	0.713	0.508
C_SPk	134.9	1.645	1.173	1.053	0.988
mean	**126.02**	**1.567**	**1.011**	**0.802**	**0.612**
SEM	6.74	0.03	0.03	0.05	0.07
*Kl_SPk	113.22	1.489	1.031	0.878	0.699
*B_SPk	114.24	1.475	1.018	0.872	0.735

Notes: SEM – standard error of mean; IR – inertia of rotation; COM –general center of mass; *Kl – Klemova: *B - Bales

The results of the comparative analysis highlight the increase in anthropometric parameters and inertia of rotation. For example, the radius of the segmental movement of the gymnast C.I. shows an increase at the level of the pointed toes by 0.139 m (1.506 m); at the COM (hip) – an increase by 0.169 m; at shoulders, an increase by 0.197 m and at arms – an increase by 0.16 m, which highlights the improvement in the technical execution of the motion amplitude.

Figure 3 presents the trajectory of COM while executing the transition from the HB to the LB –Pak salto on the uneven bars - gymnast C.I., compared to 2017.

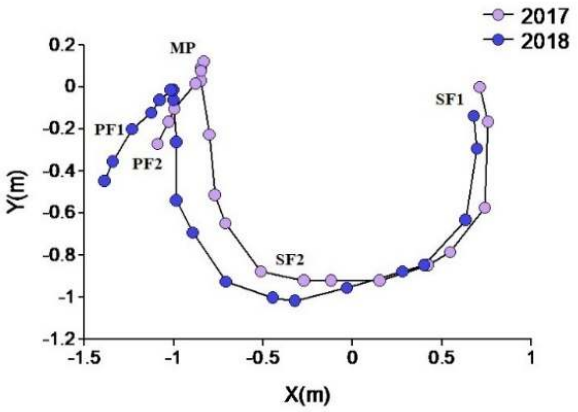
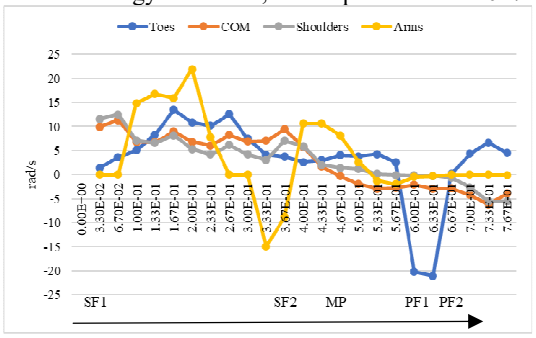


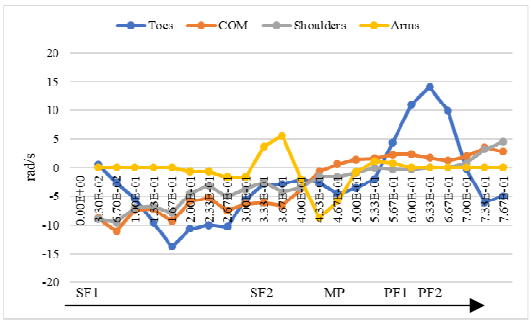
Fig. 2. *Trajectory of COM during the execution of the transition from HB to LB –Pak salto on uneven bars* (athlete C.I., 15 years)

The comparative analysis of the key moments of the technical elements within the phase structure, related to 2017, point out: *Phase of the preparatory movement*, 1- sub-phase 1 (SPh1) – horizontal body posture: the descent of COM by 0.293 m under the horizontal of HB is noticed; 2 – SPh2-LP – body posture before releasing the bar, location of COM by 0.313 m lower (0.227 m). *Phase of the basic movement*, 3 – MP – multiplication of body posture at the maximum height of the general center of mass (COM): a decrease of the flight height by 0.106 m (-0.015 m) is observed. *Phase of the concluding body posture*, 4 – CP1.1 – concluding posture 1 – grasp of HB, first contact with the bar – support, closer to LB by 0.206 m; 5 – CP1.2 – concluding posture 2, continuation of the movement – 0.299 m.

Fig. 3 (a, b) shows the values of the angular velocity during the transition from the HB to the LB – Pak salto – of the gymnast C.I., in comparison with 2017.



a) 2017



b) 2018

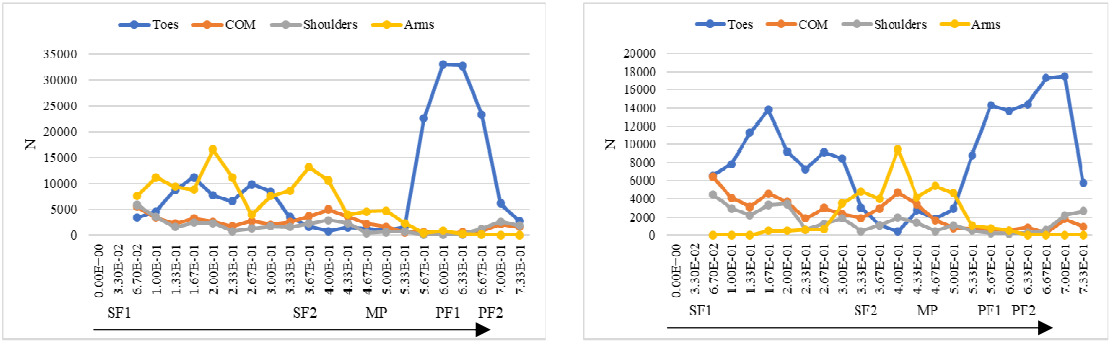
Fig. 3. *Angular velocity during the execution of the transition from HB to LB –Pak salto on the uneven bars* (athlete C.I., 15 years)

The comparative analysis of the key moments of the technique used in the phase structure reveals the following matters: *Phase of the preparatory movement*, 1- sub-phase 1 (SPh1) – horizontal body posture: it can be noticed a decrease of the angular velocity of body segments; 2 – SPh2-LP – body posture before releasing the bar; a decrease in the segments angular velocity is noticed.

Phase of the basic movement, 3 – MP – multiplication of the body posture at the maximum height of the general center of mass (COM): an increased angular velocity is observed at the pointed toes by 0.453 rad/s, at COM by 0.364 rad/s and at shoulders by 0.171 rad/s; a decrease by 2.273 rad/s is noticed at the arms.

Phase of the concluding posture, 4 – CP1.1 – concluding posture 1, grasping the HB and supporting: there is a decrease of the angular velocity of the pointed toes by 15.844 rad/s and an increase in COM, arms and shoulders, and in 5 – CP1.2 – concluding posture 2 for movement continuation – there is a decrease of the angular velocity in all segments in order to allow the movement to continue.

Figure 3 (a, b) presents the values of the force resultant during the transition from the HB to the LB – Pak salto - athlete C.I., in contrast to 2017.



a) 2017 b) 2018

Fig. 4. *Force resultant during execution of transition from HB to LB –Pak salto on uneven bars* (athlete C.I.)

The results obtained by comparative analysis reveal the following elements: during the *preparatory movement phase*, 1- sub-phase 1 (SPh1) – body horizontal posture – there are higher values at toes and COM while the shoulders have a decrease by 3060 N; 2 – SPh2-CP – body posture before releasing the bar – increase of the force value in the pointed toes by 1390 N. The *basic movement phase*, 3 – MP – multiplication of body posture at the maximum height of (COM) – increase at toes level by 580 N and decrease of COM by 520 N. *Phase of concluding posture*, 4 – CP1.1 – final posture 1, grasping the HB and supporting – a decrease at toes and arms level by 18600 N and 96.847 N and an increase at COM and shoulders by 379.087 N and 123.751 N; 5 – CP1.2 – concluding posture 2, of movement continuation: a decrease of the force value in all body segments is noticed.

In terms of performances obtained in competitions, the mean and SD of the Difficulty Score is 4.52 ± 0.13 points, higher by 0.46 points in 2017 (4.06 ±0.22 points) at $p < 0.05$; the mean of the Execution Score is 7.69 ± 0.15 points, smaller by 0.06 points in 2017 (7.75 points) at $p > 0.05$; the mean of the Final Score is 12.13 points, higher by 0.35 points in 2017 (11.78 points) at $p > 0.05$. The decreased value of the Execution Score is explained by the increase of the new difficult elements that were not yet well learned.

Discussion

As part of the research, 7 gymnasts aged 14-15 years were monitored on the uneven bars, in two international competitions of 2017 and 2018, at *Pak Salto* (3.000 - giant circles group UB, element 3.404, difficulty D) - Hang on high bar, facing low bar – swing forward, salto backward stretched between bars to clear support on low bar (FIG, 2016). In this regard, a comparative biomechanical video analysis was conducted to highlight both the evolution of the exercise content and the dynamics of Pak Salto learning on the uneven bars, compared to the execution of the elite gymnasts (1st place).

The artistic gymnastics research trends on the kinetics were divided and classified according to the research methods used (kinematics, kinetics and EMG research), fields (competition apparatus) and main topics (Tsukahara vault skill, high bar flight skill, parallel bars support skill, high bar dismount skill, floor exercise salto skill) (Han & Kwon, 2007). To help reduce the incidence and severity of injuries in gymnastics, targeted strategies for injuries prevention, based on the biomechanical analysis, have been developed (Bradshaw & Hume, 2012).

The analysis of the segmental angular characteristics helped to identify the key components of the phase structure of the execution technique used in the transition from the HB to the LB, with Pak salto on the uneven bars: a) the first phase, of the preparatory movement, SPh1 – body posture on the HB horizontal, SPh2-LP – body posture before releasing the bar; b) the second phase, of the basic movement, MP – multiplication of the body posture at the maximum height of the general center of mass (COM) and c) the third phase, of the concluding movement, CP1.1 – concluding body posture 1, grasping of LB - first contact with the bar – support, CP1.2 – concluding body posture 2 of movement continuation – preparation for the next element.

The results of the comparative analysis of the transition from HB to LB –Pak Salto on the uneven bars – showed the value recorded by the angle between hip and torso (a) and the angle between torso and arms (b) in the phase structure of the movement. There were calculated the biomechanical parameters required for the biomechanical study regarding the inertia of the movement, the radius of body segments movement, the change of the angular velocity and the force resultant.

In the opinion of Grosu, E. F. (2004), the main current directions of development of the routines on uneven bars focus on derivation, concentration, borrowing of procedures from boys for girls' routines and vice versa (a less common situation) (transfer - Potop, 2007) (Potop & Crețu, 2018). There are studies that present a biomechanical analysis of an innovative technique on the uneven bars in international gymnastics competitions, in terms of trajectory motion of body's center of gravity, the angle variation diagram of shoulder and hip joints and the Coriolis principle (Xin & Li, 2000). Other studies deal with the kinematic dynamic structure of the

dismount by giant swings backward executed effectively on horizontal bar and uneven bars (Knoll, 2001). There were also studied the various strategies showed by elite and beginner gymnasts in counter movement forward during the flight on the uneven bars (Huchez et al., 2013) and the biomechanical analysis of high amplitude Tkachev salto (Čuk, Atiković, & Tabaković, 2009). A motion analysis of the "Shaposh" skill (difficulty D) is conducted regarding the flight from the high bar to the low bar on uneven bars in order to suggest a training methodology (Mustafa & Abdwahhab, 2020).

The results of the performances achieved in competitions highlight the increased difficulty of the competition routine and the decrease of the score for execution because of the increase in the number of new elements of difficulty, with an insufficient level of learning.

The methodological-scientific literature shows that in studying and learning the gymnastics exercises technique based on the method of motion postural cues, the key elements of the sports technique in the phase structure of the exercises are subject to development and improvement. This development and improvement is due to the training programs suggested to increase the quality of the movement control, taking into account the level of sports fitness, the specificity and complexity of sports exercises (Sadowski et al., 2012; Boloban, 2013; Biegajlo et al. 2022). There are also evaluated and characterized the external load trends related to flight elements in elite level uneven bars routines (Ferreirinha et al., 2010), the evolution of the difficulty value of the partial or full routines and the specific types of elements on the uneven bars (Ferreirinha & Carvalho, 2011).

Conclusions

The review of the specialized literature complements the biomechanical study with additional information on the research methods, fields and main topics investigated regarding the uneven bars.

There were identified the key components within the phase structure of the element included in group 3- giant circles on uneven bars – transition with Pak Salto from hang on high bar, facing low bar – swing forward, salto backward stretched between bars to clear support on low bar.

The biomechanical video analysis highlighted the spatio-temporal characteristics of the COM trajectory, the value of the angular velocity and force resultant in the execution of the transition from the HB to the LB with Pak Salto flight phase on the uneven bars, in accordance with the method of motion postural cues, which can serve as didactic materials necessary for the learning process.

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References

Boloban, V., & Potop, V. (2014). Biomechanical characteristics of key elements of sports technique of apparatus exercises in the women's gymnastics all-around. *Science in Olympic sport*, 1, 44-49.

Biegajlo, M., Nogal, M., Niźnikowska, E., Mastalerz, A., Wiśniowski, W., & Niznikowski, T. (2022). Key elements of sports technique in the phase structure of acrobatic exercise that connects moves performed on a beam. *Journal of Physical Education and Sport*, 22(4), 1061-1071.

Bradshaw, E. J., & Hume, P. A. (2012). Biomechanical approaches to identify and quantify injury mechanisms and risk factors in women's artistic gymnastics. *Sports Biomechanics*, 11(3), 324-341. DOI:10.1080/14763141.2011.650186

Code of Points Women's Artistic Gymnastics, 2017 – 2020, Approved by the FIG Executive Committee updated after the WAG Intercontinental Judges' Course from 12 to 18 December 2016, Fédération Internationale de Gymnastique (FIG, 2016).

Čuk, I., Atiković, A., & Tabaković, M. (2009). Tkachev salto on high bar. *Science of gymnastics journal*, 1(1), 5-13.

Han, Y. S., & Kwon, O. S. (2007). Analysis of the Research Trend of Artistic Gymnastics on the Sports Biomechanics. *Korean Journal of Sport Biomechanics*, 17(2), 93-101. DOI:10.5103/KJSB.2007.17.2.093

Huchez, A., Haering, D., Holvoet, P., Barbier, F., & Begon, M. (2013). Differences between expert and novice gymnasts performance of a counter movement forward in flight on uneven bars.

Forminte, V. N., Potop, V., Micu, R., & Grosu, E. F. (2020). Optimal kinematic characteristics of the uneven bars dismounts–a case study. Discobolul–Physical Education, Sport and Kinetotherapy Journal, 59(1), 70-80. DOI:10.35189/dpeskj.2020.59.1.7.

Ferreirinha, J., Marques, A. T., Alves, F., Carvalho, J., Côrte-Real, C., & Silva, A. J. (2009). Evolution of body position in uneven bars routines: Influence of" in bar" elements. Motricidade, 5(3), 75.

Ferreirinha, J., Carvalho, J., Côrte-Real, C., & Silva, A. (2010). The evolution of flight elements in competitive uneven bars routines. *Science of Gymnastics Journal*, 2(1), 49-59.

Ferreirinha, J., & Carvalho, J. (2011). The evolution of real difficulty value of uneven bars routines from elite gymnasts in last 5 Olympic cycles. *Science of gymnastics journal*, 3(1), 15.

Grosu, E. F. (2004). *Paralele inegale din gimnastica artistică feminină* [Uneven Bars in Women's Artistic Gymnastics], Cluj-Napoca: GMI

Hiley, M. J., & Yeadon, M. R. (2013). Investigating optimal technique in a noisy environment: application to the upstart on uneven bars. Human Movement Science, 32(1), 181-191.

Irwin, G., Exell, T. A., Manning, M. L., & Kerwin, D. G. (2014). Biomechanical evolution of the Tkachev on uneven bars in female gymnastics. *International Biomechanics*, 1(1), 21-28. DOI:10.1080/23310472.2014.983165

Irwin, G., Manning, M., & Kerwin, D. G. (2011). Kinematics and angular momentum contributions to the toe-on Tkachev on uneven bars in female gymnastics. In ISBS-Conference Proceedings Archive.

Kalinski, S. D., Kezić, A., & Jelaska, I. (2020). Composition of female gymnastics uneven bars routines: insight through five Olympic cycles. *Acta Kinesiologica,* 14 (1), 92-100.

Kerwin, D. G., & Irwin, G. (2010). Musculoskeletal work preceding the outward and inward Tkachev on uneven bars in artistic gymnastics. *Sports Biomechanics*, 9(1), 16-28. DOI: 10.1080/14763141003690203

Kim, S. K., Kim, S. E., & Jang, D. S. (2013). A kinematic analysis of glide kip motion on the uneven bars. *Korean Journal of Sport Biomechanics*, 23(4), 307-318.

Knoll, K. (2001). The kinematic dynamic structure of effective giant swings backward prior to difficult dismounts and flight elements on horizontal bar and uneven bars. In ISBS-Conference Proceedings Archive.

Manning, M. L., Irwin, G., Gittoes, M. J., & Kerwin, D. G. (2011). Influence of long swing technique on the kinematics and key release parameters of the straddle Tkachev on uneven bars. *Sports Biomechanics*, 10(3), 161-173.

Manoni, A., de Leva, P., Carvelli, E., Mallozzi, L., Grosso, F., & Milani, M. (1992). Biomechanical analysis of seven forward giant swings at the uneven parallel bars. In ISBS-Conference Proceedings Archive.

Mustafa, Q. M. S. A. A., & Abdwahhab, G. H. (2020). Biomechanical analysis of "Shaposh" skill on an uneven bar as a basis for developing qualitative exercises. *Journal of studies and researches of sport education*, (64).

Nyman, E. (2020). Biomechanics of gymnastics. In *Gymnastics medicine* (pp. 27-54). Springer, Cham. DOI:10.1007/978-3-030-26288-4_3

Prassas, S., Kwon, Y. H., & Sands, W. A. (2006). Biomechanical research in artistic gymnastics: a review. *Sports Biomechanics*, 5(2), 261-291. DOI:10.1080/14763140608522878

Petković, E. (2019). Kinematic modeling of the technique Stalder backward to handstand on the uneven bars. *Facta Universitatis. Series: Physical Education and Sport*, 031-042. DOI:10.22190/FUPES190317006P

Potop, V., & Cretu, M. (2018). Analysis of physical training influence on the technical execution of the dismounts off the uneven bars. *Pedagogics, psychology, medical-biological problems of physical training and sports*, (1), 28-34.

Sadowski E., Boloban V., Niźnikowski T., Mastalerz A., Wisniowski W., Biegajło M. (2012). Motion postural cues as the method of analyzing and assessing the indices of kinematic structure of key elements of sports technique of basic connection of exercises "turn over forward – salto forward tucked. *Theory and Practice of Physical Culture*, 7, 98-102.

Thomas, K., & Bradshaw, E. J. (2011). Giant swings with turns completed to handstand on uneven bars. In ISBS-Conference Proceedings Archive.

Xin, P., & Li, W. S. (2000). Kinematic characteristics of the Steinemannstemme move on the uneven bars: a case study. In ISBS-Conference Proceedings Archive.