Journal of Physical Education and Sport ® (JPES), Vol. 22 (issue 8), Art 232, pp. 1848 - 1853, August 2022
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Particularities of the biomechanical characteristics of learning the acrobatic exercises on balance beam in Junior III category (aged 9-10 years)

VLADIMIR POTOP[1], MARIANA CÎMPEANU[2], CAROLINA MOGA[3], VALERIU JURAT[4], CARMEN MANOLE[5], ANVAR ESHTAEV[6]
[1, 5] Department of Physical Education and Sport, University of Pitesti, ROMANIA
[2] „Dinamo" School Sports Club Bucharest, ROMANIA
[3,4] State University of Physical Education and Sport, Chisinau, MOLDOVA
[6]Uzbec State University of Physical Culture and Sport, Tashkent, UZBEKISTAN

Published online: August 31, 2022
(Accepted for publication August 15, 2022)
DOI:10.7752/jpes.2022.08232

Abstract
This paper aims at showing which are the particularities of the biomechanical characteristics in learning the acrobatic exercises on balance beam by the junior gymnasts of category III. **Material.** The study was conducted within the Gymnastics Department of the „Dinamo" School Sports Club of Bucharest, over a period of 2 years (2018- 2019). The subjects of the study were 4 gymnasts level 3 (9-10 years old). The biomechanical analysis of the acrobatic exercises on balance beam was performed using the Physics ToolKit program. The linear and branching algorithmic programming was employed for learning and making better the acrobatic exercises specific to this gymnastics category. The statistical analysis and the graphical representation of data were done by means of KyPlot program. The performances on balance beam were monitored in three national competitions (C): C1 –National School Championship, junior III, level 1, 2018; C2 - National Championship for Juniors III, level 1, 2018 and C3 - National School Championship, junior III, level 2, 2019. **Results.** This study highlights the efficiency of implementing the algorithmic programs for improving the acrobatic exercises on balance beam in juniors III, level 1 and 2. The dynamics of acrobatic exercises learning according to the classification program and the improvement of these exercises led to the good results achieved during the national competitions. The video biomechanical analysis focused on the study of the technical execution of two or three acrobatic elements and the round-off back tuck dismount. At the same time, the trajectory of the body general center of mass and the angular velocity of the segments of the body in each moment and position of the exercise phasic structure were analyzed. Also, the particularities of the kinematic characteristics consistent with the movement general bases, direction of execution (from right to left or vice versa), amplitude of the split, rhythm – tempo of execution (succession of arms-legs movement) and execution velocity were identified. **Conclusion.** The use of the computerized video method for the biomechanical analysis of the routines on balance beam helped to identify the particularities of technique basic elements, the deeper knowledge of the phasic structure and last but not least the execution faults.
Key words: **balance beam, algorithmic learning, improvement, juniors, kinematic characteristics, performance**

Introduction

Artistic gymnastics, with its particular developmental features, shows remarkable progress. The changes to the Code of Points determine new trends and guidelines of training. The modern trends in technology come from both the field of didactic technology and the field of biomechanics as a science branch (Potop & Crețu, 2015). The balance beam is an apparatus that belongs to women's artistic gymnastics. It can be described as a balance apparatus. In terms of biomechanics, the balance during the exercises can be adjusted and maintained by observing the law of the permanent projection of the body center of gravity on a very narrow supporting surface (Atılgan et al., 2012; Aleksić-Veljković et al., 2019). The methodology of learning the exercises on balance beam is not complicated. It starts with learning the exercises on the floor, after which a surface progressively narrower and higher is used. The use of didactic technologies through linear and branching algorithmic learning schemes on balance beam can efficiently contribute to a better technique of execution of the acrobatic exercises (Potop et al., 2015). The studies of the researchers who promote the computerized video method for the analysis of the sports technique concerning the biomechanics and also the recommendations of well-known companies in this field (Ariel Dynamics, Quintic Biomechanics, Neat System, Swinger, World in Motion, Sport Card, Mikromak, Noldus etc.) propose the use of programs and equipment for images analysis or the purchase of complete systems meant to implement this method (Crețu, M., Simăn, I. I., & Bărbulescu, M. (2004). This paper is meant to highlight the particularities of the biomechanical characteristics of learning the acrobatic exercises on balance beam at the junior gymnasts of category III (9 – 10 years old).

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

Material and methods

To solve these problems, a study was organized in the Gymnastics Department of "Dinamo" School Sports Club of Bucharest throughout 2 years (2018- 2019). The subjects of the study were 4 gymnasts of category III, level 1 (9-10 years). The experimental research used the case study method aiming to present the dynamics of mastering the acrobatic exercises on balance beam.

There were used the methods below:

-*video method of biomechanical analysis* of the acrobatic exercises; the Kinovea and Physics ToolKit programs were used to measure the kinematic and dynamic characteristics;

- *method of linear and branched algorithmic programming* for learning and perfecting the acrobatic exercises on balance beam;

- *statistical-mathematical method* with the help of KyPlot program for the calculation of the main descriptive indicators: mean, SEM –standard deviation of the mean, SD - standard deviation;

- *method of data graphical representation*.

Performance capacity on balance beam:

- C1 - National School Championship, juniors III, level 1, 2018, full exercise on balance beam evaluated through the 2 scores awarded: score D (difficulty) and score E (execution), calculating the average between them.

- C2 - National Championship for Juniors III, level 1, 2018, full exercise on balance beam evaluated through the 2 scores awarded: score D and score E, calculating the average between them.

- C3 - National School Championship, juniors III, level 2, 2019, full exercise on balance beam evaluated through the 2 scores awarded: score D and score E, calculating the average between them.

Algorithmic program for learning the back walkover on one leg on balance beam:

Set I (providing the necessary motor support for learning):

- Standing –vertical in-place jumps with arms (A.) up and right leg (L.) swing forwards, with help;
- Standing – back jump on stacked mats in extension, arms up and right leg to the chest.

Set I (actual learning):

- Flick-flack backwards on one leg with stop in handstand, split legs, with help;
- Depth flick –flack backwards on the right leg (from trampoline, mat), with and without help;
- Flick –flack backwards on the right leg, with and without help;
- Flick-flack backwards on the right leg, on the low balance beam, with and without help.

Set III (consolidation and improvement):

- Flick-flack on one leg, on competition balance beam;
- Slow back walkover, with flick-flack on one leg, on the competition balance beam;
- Two back flick-flacks on one leg, connected, on the competition balance beam;
- 3 elements connected: Slow back walkover – flick-flack on one leg;
- 3 flick-flacks on one leg, connected;
- 3 elements connected: 2 flick-flacks on one leg – back walkover;
- Flick –flack on one leg, connected with back salto on one leg on the floor and on the balance beam, with and without help.

Results

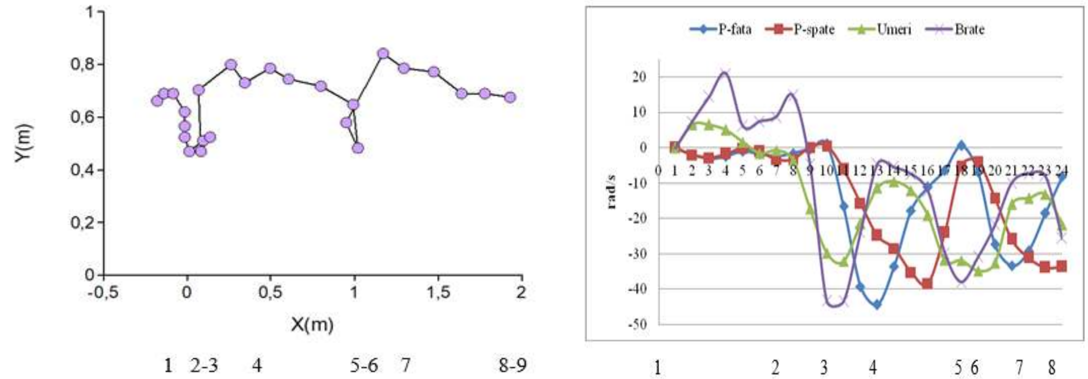
In table no.1 are listed the results of the indicators related to the biomechanical analysis of the acrobatic exercises on balance beam, regarding the rotational inertia and the radius of body segments movement around the axis of rotation of the general center of gravity (GCG).

Table no. 1. Values of specific indicators in the biomechanical analysis of acrobatic exercises on balance beam

Code of acrobatic elements	I.R. ($kg \cdot m^2$)	Radius of body segments motion (m)				
		L-front	L-back	Shoulders	A-in front	A-behind
2FF1P	14.09	0.637	0.625	0.380	0.657	
Cob_RSG	14.09	0.587	0.575	0.345	0.616	0.617
RLÎ-2FFÎ1P*	14.09	0.710	0.681	0.396	0.771	
		0.677	0.688	0.407	0.786	
3FFÎ1P*	14.09	0.617	0.609	0.380	0.644	
		0.672	0.680	0.376	0.727	
2FFÎ1P-FF2P*	14.09	0.609	0.606	0.371	0.629	
		0.643	0.646	0.378	0.746	
Mean	14.09	**0.644**	**0.638**	**0.379**	**0.697**	
SD	0.00	0.04	0.04	0.02	0.07	
Cv%	0.00	6.29	6.53	4.78	9.74	

Notes: * - the analysis of the 3 elements was divided into two parts: 1 element and 2 elements connected; 2FF1P – 2 flick-flacks on one leg; RLÎ-2FFÎ1P – slow walkover backwards – 2 flick-flacks on one leg; 3FFÎ1P – 3 flick-flacks on one leg; 2FFÎ-FF2P – 2 flick-flacks on one leg backwards – flick-flack on 2 legs; I.R. – rotational inertia; L-front – front leg; L-back – back leg; A-in front and behind at round-off dismount; A (in front and behind) – arms in acrobatic elements.

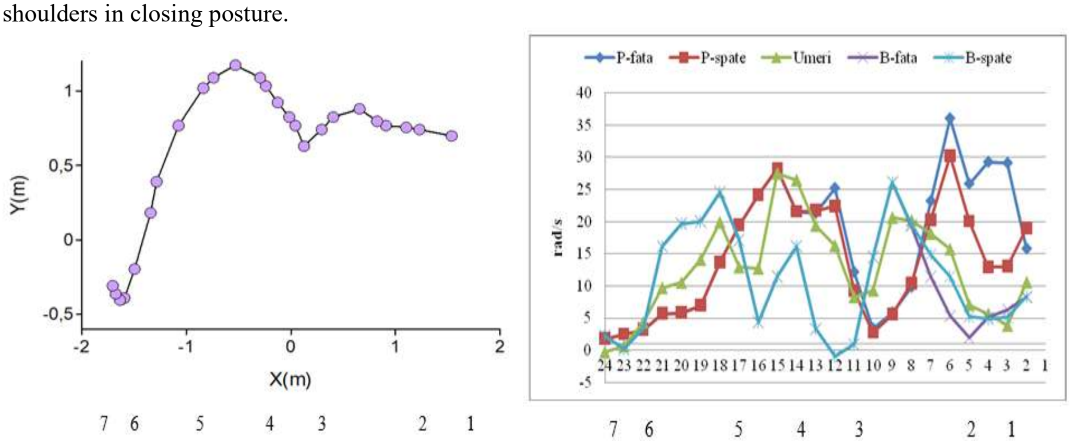
Figures 1, 2, 3, 4, 5 show the trajectory of the center of gravity and the body segments angular velocity throughout the acrobatic exercises analyzed in this paper. The graphs point out the biomechanical characteristics specific to the phasic structure of the elements executed in direct connection.



a) b)

Fig. 1. *Execution of 2 flick-flacks backwards on one leg, connected*
a) Trajectory of GCG, b) Angular velocity

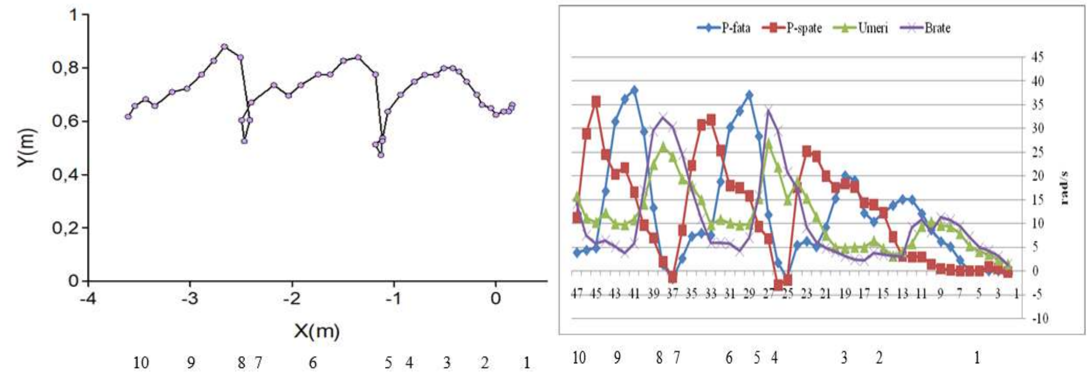
Figure 1 presents the execution of 2 flick-flacks backwards on one leg, connected (level 2 amendment). Fig. a) shows 9 moments concerning the trajectory of the General Center of Gravity (GCG) (hip): 1 – initial posture; 2-3 launching posture (beginning and end); 4 – split handstand; 5-6 – closing posture and launching posture for the second flick-flack (*fault* of execution – knees forwards); 7 - split handstand; 8-9 - closing posture (beginning and end). Fig. b) shows the graph of the angular velocity at the segments of the body, where the angular velocity is higher at arms level (preparatory movement), then an increase of the value of the front leg(swing) in flight phase and handstand; afterwards, the arms movement in the launching posture of the second flick-flack, the movement of front and back legs equalize successively, then the movement of arms and shoulders in closing posture.



a) b)

Fig 2. *Execution of a back tuck dismount directly connected from a round-off*
a) GCG Trajectory; b) Angular velocity

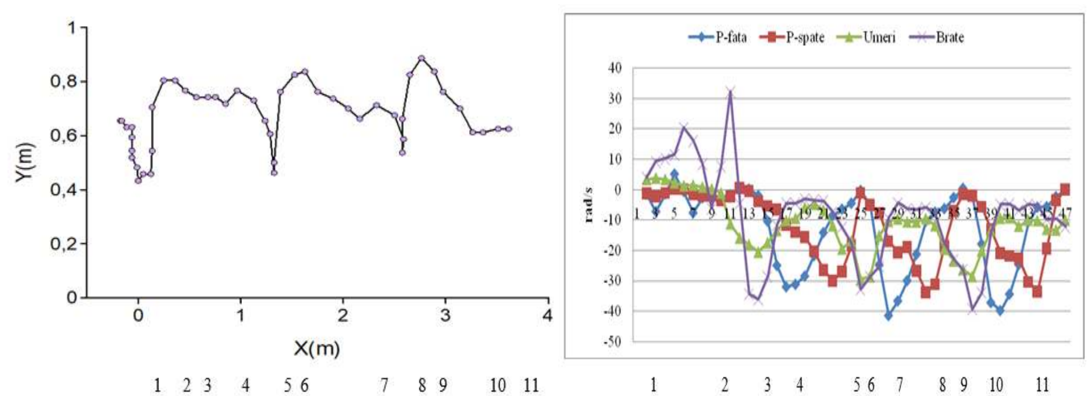
Figure 2 presents the execution of a back tuck dismount directly connected from a round-off (level 2 amendment). Fig. 2a) highlights 7 moments during the GCG trajectory: 1 – placing the arm (A) in front (first hand), 2 – placing the arm behind (second hand); 3 – moment of take-off (launching/starting posture); 4 – ascending flight phase of the salto (horizontally dorsal); 5 - descending flight phase of the salto (horizontally ventral); 6 – landing (damping); 7 – closing posture (ending). Figure 2b) shows the graph of the angular velocity of the body segments when a round-off back tuck dismount is performed. Stages of the execution: posture 1 - one arm is placed in front (first hand); the angular velocity is bigger in the back leg (swing movement), 2 – placing the arm behind (second hand) while the value increases in the front leg; 3 – before take-off, launching/starting posture – higher value at arms level; 4 – during the ascending flight phase of the salto, the arms are brought to the knees and not the other way round - braking of the rotation backwards; in the dorsal horizontal posture, the highest value is observed at the back and front legs, then at shoulders and arms ; 5 – descending flight phase of the salto (ventral horizontal posture), where the biggest values is recorded at legs and arms, as the shoulders brake the rotational movement; 6 – landing (damping)– there are close values in all segments, with a slight increase in shoulders due to rising and in arms; 7 - closing – the angular velocity of shoulders decreases.



a) b)

Fig. 3. *Execution of 3 acrobatic elements connected: slow walkover backwards - 2 flick-flacks on one leg*
a) Trajectory of GCG; b) Angular velocity

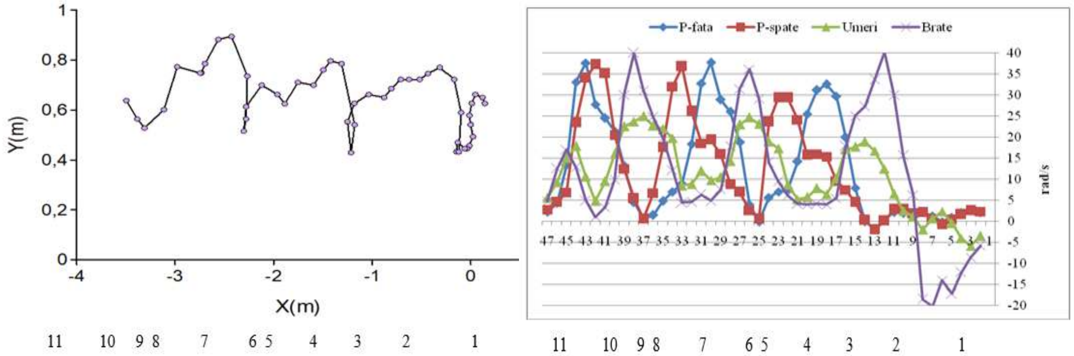
Figure 3 presents the execution of 3 acrobatic elements connected: slow walkover backwards - 2 flick-flacks on one leg (exercise for improving the flick-flack on one leg). Fig. 3a) shows the trajectory of body GCG (hip) with 10 moments: 1 – initial posture; 2- slow extension of torso backwards, support on arms; 3 – split handstand; 4-5 – closing posture and launching posture into flick-flack; 6 - split handstand; 7-8 - closing posture and launching to the second flick-flack; 9 - split handstand; 10 – closing posture. Figure 3b) shows the graph of the angular velocity recorded at the segments of the body related to the axis of rotation of GCG as follows: moment 2- slow extension of torso backwards, support on arms; higher angular velocity of the front leg; then torso turning over with velocity at shoulders level, the at the back leg and arms. Moment 3 – split handstand , the angular velocity increases in the back leg close to the front leg and shoulders; the arms are in support position on the balance beam; 4-5 – closing posture and launching posture to flick-flack; there are high values when arms are moved, then the shoulders and the legs which come into action; 6 - split handstand in which the value is higher in the front leg and lower in the back leg, followed by the value of shoulders and arms; 7-8 – closing posture and launching to the second flick-flack; the movement of arms, shoulders, back leg and front leg gets equal values; 9 - split handstand, with higher velocity of the front and back leg, then of shoulders and arms; 10 – closing posture – landing. One can notice the arms movement for raising the torso – shoulders, then slowing of the rotation with back and front leg.



a) b)

Fig. 4. *Execution of the connection of 3 acrobatic elements: 3 flick-flacks on one leg*
a) Trajectory of GCG, b) Angular velocity

Figure 4 shows how were performed 3 acrobatic elements connected: 3 flick-flacks on one leg (exercise for improving the flick-flack on one leg). Fig. 4 a) presents the trajectory of body GCG (hip). There are 11 moments: 1 - initial posture; 2-3 launching posture; 4 – split handstand; 5-6 – closing posture and launching to the second flick-flack; 7 - split handstand; 8-9 - closing posture and launching to the third flick-flack; 10 - split handstand; 11 – closing posture. Figure 4 b) shows the graph with the angular velocity reached by the body segments. In moment 2-3 (launching posture), there is a bigger angular velocity when the arms are directed backwards and before launching, when shoulders intervene; 4 – split handstand; the value of angular velocity is bigger at front and back legs, followed by shoulders and arms movement; 5-6 – closing posture and launching to the second flick-flack; the value of the arms movement is higher; 7 - split handstand; one can notice the movement of front and back legs, then the movement of shoulders and arms; 8-9 - closing posture and launching to the third flick-flack; the arms and shoulders get into action, then the arms accelerate, followed by the legs (front and back); 10 - split handstand; increased value of the front and back legs turning over and distance, followed by shoulders and arms; 11 – closing posture – landing: arms(for raising the torso) and shoulders.



a) b)

Fig. 5. *Execution of 3 acrobatic elements connected: 2 flick-flacks on one leg – one flick-flack on 2 legs a) Trajectory of GCG, b) Angular velocity*

Figure 5 highlights the execution of 3 acrobatic elements connected: 2 flick-flacks on one leg – flick-flack on 2 legs (exercise for the improvement of the flick-flack on one leg). Fig. 5 a) shows the trajectory of body GCG. There are 11 moments: 1 - initial posture; 2-3 launching posture; 4 – split handstand; 5-6 – closing posture and launching to the second flick-flack; 7 - split handstand; 8-9 - closing posture and launching to the third flick-flack; 10 - split handstand; 11 – closing posture. Fig. 5 b) presents the graph of body segments angular velocity. Moments 2-3: launching posture; one can observe the velocity of arms movement backwards and forwards, enabling the legs to come into action; 4 – split handstand; high value at the front leg, then the back leg, shoulders and the support hands; 5-6 – closing posture and launching to the second flick-flack; the value of arms and shoulders movement increases at take-off; then the legs come into action; 7 - split handstand; the value of front and back legs movement increases, then the value of shoulders and arms; 8-9 - closing posture and launching to the third flick-flack; the movement of arms, shoulders and take-off can be observed; 10 - split handstand; the legs have different values; 11 – closing posture – landing. Legs have almost equal value.
Table no. 2 shows the results of the performances obtained in competition by the junior gymnasts III (9-10 years old) who participated in C1, C2 - 2018 and C3 – 2019.

Table no. 2. *Results achieved in competitions (2018-2019)*

Surname First name	C1			C2			C3		
	D	E	NF	D	E	NF	D	E	NF
C.A-M.	4.500	8.800	13.300	4.500	8.900	13.400	4.00	8.200	12.00
P.M-I	4.500	7.700	12.200	4.500	8.080	12.575	-	-	-
P.M-A.	4.500	8.000	12.500	4.500	7.800	12.300	-	-	-
E.R-E	4.500	7.000	11.500	4.500	6.500	11.000	-	-	-
X	4.5	7.875	12.375	4.5	7.820	12.32	-	-	-
SED	0	0.37	0.37	0	0.49	0.49	-	-	-
SD	0	0.75	0.74	0	0.99	0.99	-	-	-

Notes: C1 - National School Championship, 2018; C2 - National School Championship for Juniors III, teams and all-around, 2018; C3 - National School Championship, Buzău, April 2019; D – difficulty; E – execution; NF – final score.

The performance analysis reveals the fulfilment of the Difficulty amendments at level 1, an average of about 7.800 points of the Execution score in the championships C1 and C2 and 8.200 points in the championship C3 (C.A-M), with a mean of 12.300 points in Final score at level 1 and 12.000 points at level 2. These results reveal the content of the amendments in a different way, consistent with the Difficulty value of the exercises in Juniors III level 1 and 2 and the acquisition of the acrobatic elements which are an important part of the exercise.

Discussion

For highlighting the most specific aspects related to the mastering of the acrobatic exercises on balance beam at this age and category of gymnasts, the method of algorithmic learning was used. The results prove the efficiency of the algorithmic programs implementation meant to improve the acrobatic exercises on balance beam. In this sense, three sets of exercises were applied for: 1) providing the motor support; 2) learning the characteristics of the basic movement; 3) assimilating and improving the element.

Five biomechanical studies were performed; their indicators are listed in table no. 1 and the acrobatic elements are described in the Notes under the table. The biomechanics video method was applied according to the sports technique analysis method used in the postural orientation of the movement of body segments (Potop et al., 2015). This method helped to identify the principal technique components in the phasic structure of the acrobatic exercises on balance beam. Each acrobatic element, depending on its technical structure, highlighted the launching posture, the intermediate posture (multiplication of body position) and the final posture (closing) which fulfilled the function of launching posture for the next element in a connection of 2 or 3 elements (Potop et al., 2013).

The importance of the biomechanical study on balance beam has been highlighted by some specialists. For the scientific argumentation of the links between the indicators specific to the biomechanical properties, studies were developed regarding the correlative analysis. The results of measuring these indicators show which is the value of the rotational inertia. The indicators of the biomechanical characteristics of the legs motion radius while executing the acrobatic elements have the following particularities: front leg – swing movement and back leg – movement of pushing/impelling; the radius of shoulders and arms movement (amplitude of movement) reveals a difference between the arms (the first and the second) while executing the round-off dismount (Knoll, 1996; Kim, Ryu, & Jeo, 2012, Potop et al., 2015, Aleksić-Veljković et al., 2019). Asymmetry in the use of the lower limbs can influence the results on balance beam and the risk of injury; the unilateral distribution of the load can be associated with the unilateral predominance of the injuries and this fact should be analyzed in further research (Bučar et al., 2016). Some studies deal with the acrobatic exercises on balance beam in terms of biomechanical properties according to their indicators (Potop, V., Niculescu, G., Timnea, O.C., 2013). The authors who focused on the dismounts off balance beam analyzed from biomechanics point of view highlighted the reaction of the force to the salto (Brown, et al., 1996; Potop, Manole & Andreyeva, 2014; Potop & Cretu, 2015).

Conclusions

The video biomechanical analysis highlighted the study of the technical execution of two or three acrobatic elements and the round-off back tuck dismount. It was also analyzed the trajectory of the body general center of gravity and the angular velocity of the segments of the body in every moment and position of the exercise phasic structure. Also, the particularities of the kinematic characteristics consistent with the movement general bases, direction of execution (from right to left or inversely), amplitude of the split, rhythm – tempo of execution (succession of arms and legs movement) and execution velocity were identified.

The use of the computerized video method for analyzing the exercises on balance beam with regard to biomechanics helped to find out the particularities of technique basic elements, the deeper knowledge of the phasic structure and last but not least to identify the execution faults.

References

Aleksić-Veljković A, Živčić Marković K, Milčić L. 2019, The relationship between chosen kinematic parameters of the aerial cartwheel on the balance beam during skill learning. *Baltic Journal of Health and Physical Activity,*11(1), 18-23. DOI:10.29359/BJHPA.11.1.02.

Atılgan, A. O. E., Akın, M., Alpkaya, U., & Pınar, S. (2012). Investigating of relationship between balance parameters and balance loss of elite gymnastics on balance beam. *Journal of Human Sciences*, 9(2), 1260-1271.

Brown, E.W., Witten, W.A., Weise, MJ., Espinoza, D., Wisner, D.M., Learman, J., Wilson, D. 1996, Attenuation of ground reaction forces in salto dismounts from the balance beam. *14 International Symposium on Biomechanics in Sports* (pp. 336-338). Funchal - Madeira, Portugal.

Bučar Pajek M., Hedbávný P., KalichováM., Čuk I. 2016, The asymmetry of lower limb load in balance beam routines. *Science of Gymnastics Journal*, 8(1): 5 – 13.

Crețu, M., Simăn, I. I., & Bărbulescu, M. (2004). *Biomechanics of back giant on uneven bars*. Publishing House of Pitești University, 17-23.

Kim, K-W., Ryu, Y., Jeo, K-K., 2012, A Kinetics Analysis of Tucked Backward Salto on the Balance Beam. *Korean Journal of Sport Biomechanics*, 22(4), 395-340. DOI:10.5103/KJSB.2012.22.4.395

Knoll, K., 1996, Analysis of acrobatic trumbling exercises on floor and balance beam. *14 International Symposium on Biomechanics in Sport,* Funchal-Madeira – Portugal, p.325-328.

Potop, V., Manole C., Andreyeva, N.O., 2014, Biomechanical characteristics of the dismounts off beam of junior gymnasts 12 -15 years old. *Journal of Physical Education and Sport*, 14(3), 406 - 412, DOI:10.7752/jpes.2014.03062

Potop, V., & Cretu, M., 2015, Biomechanical characteristics of the synchronization of key elements of sport technique of the complex dismounts off beam. *Journal of Physical Education and Sport*, 15(2), 324 – 329. DOI:10.7752/jpes.2015.02049.

Potop, V., Grigore, V., & Gavojdea, A. M. (2015). Implementation of e-learning in the specific didactics on balance beam in women's artistic gymnastics. *In The International Scientific Conference eLearning and Software for Education* (Vol. 3, p. 306). " Carol I" National Defence University. DOI:10.12753/2066-026X-15-227.

Zaporozhanov, V. A., Borachinski, T., & Nosko, Y. N. (2015). Assessment of children's potentials in dynamic of initial stage of sport training. *Journal of Physical Education and Sport*, 15(3), 525-530. DOI:10.7752/jpes.2015.03079.