International Journal of Emerging Research in Management &Technology
ISSN: 2278-9359 (Volume-6, Issue-1)

Research Article | **January 2017**

Analysis of Biomechanical Characteristics of Acrobatic Elements on Balance Beam

[1]Potop Vladimir[*], [2]Timnea Olivia Carmen
[1]Professor, Doctor of Science, [2]Associate Professor, PhD
[1, 2]Physical Education and Sport Faculty, Ecological University of Bucharest, Romania

DOI: 10.23956/ijermt/V6N1/111

Abstract—

The scientific argument is to highlight the kinematic and dynamic characteristics of the key components of sports technique used for the acrobatic elements on balance beam. These characteristics, submitted to computerized biomechanical video analysis, contribute to the assessment of technical training level and methodological orientation for technical execution improvement. This scientific approach has led to the organization of a study conducted from 2012 to 2013 with a group of 13 junior gymnasts aged 12 to 15 years, members of Juniors Olympic team of Izvorani. Biomechanical analysis has been made using Physics Toolkit program and movement postural orientation method, pointing out the key elements of sports technique on balance beam. The study results revealed the anthropometric and biomechanical indicators necessary for biomechanical analysis of the acrobatic elements used in the competitive exercises on balance beam executed separately, in connection or mixed way by junior gymnasts aged 12 to 15. The results also revealed the influence of the kinematic and dynamic characteristics on the technical execution consistent with the performances achieved in competitions.

Keywords— balance beam, kinematics, dynamics, sports technique, performance

I. INTRODUCTION

Artistic gymnastics currently registered remarkable progresses, showing that it develops in accordance with the performance sports trends. Over the preparation of the Olympic cycles it has been created the concept of development and improvement of artistic gymnastics, the argumentation of methodology which allows performing the multi-annual sports training (e.g. [1], [2], [3]). The basic trends specific to women's artistic gymnastics are the following ones: increase of sports mastership, increase and rivalry of competitive programs, processing of new complex routines, sports mastership that reaches virtuosity; improvement of components that provide the training of high classification gymnasts (e.g. [4]).

Biomechanical researches in artistic gymnastics can be made using biomechanical methods and also some methods taken from other fields of knowledge (pedagogical, mechanical, physiological, psychological, medical ones etc.), mainly intended to highlight the features of movement on various apparatus by selecting the means of data recording, processing and analysis (e.g. [5], [6]).

Balance beam is considered one of the most difficult events specific to women's artistic gymnastics; it can be characterized as an apparatus of balance par excellence, both physically and mentally. In terms of biomechanics, the mastery and the adjustment of balance during routines on balance beam can be achieved by respecting the logical principle of permanent projection of the body gravity centre on the bearing surface so narrow. In conformity with international regulations(e.g. [7]), the routine on balance beam must include a mount, elements belonging to different structural groups (acrobatic, gymnastic, mixed elements), elements next to the balance beam. The whole combination must be characterized by dynamism, changes of rhythm and continuity. The end of the exercise (dismount) must be consistent with the difficulty of the whole and with the specific requirements of the competition (e.g. [8]).

The location of the support segments or, easier said, the location of hands and feet on the apparatus, are important technical elements of movements on beam. Of course, different exercises require different supports. Taking into account a work order with soles placed in longitudinal standing position, we can point out the following matter: the symmetrical and asymmetrical position of the feet. The third position is common in the execution of the leap "from tempo", in a "round-off –flick" connection, "flick-leap" and so on. In biomechanical terms, these working positions are worse for the flip than the symmetrical position. The technical rules on beam highlight that the own power is maintained during the support on feet, but during the handstand too. There are also several variants of putting the palms on the beam, some of them used for the execution of many static and dynamic exercises - the symmetrical position; but the asymmetrical location too is a good position enabling to feel the apparatus (e.g. [9]).

Regarding the biomechanical peculiarities and characteristics on beam, one can point out some issues such as: the role of posture and muscle tone in maintaining the balance – one of the main conditions for gymnast's rational working posture, especially the stand up posture, from which the majority of elements on balance beam are executed; the technical elements with static balance and dynamic balance (e.g. [10]).

In terms of pushing from launching posture– standing, during the execution of the acrobatic elements on balance beam, these ones are performed in " support - sports system", presenting some complex biomechanical characteristics of motor movement, where the technical details are presented by many specialists in the training and development process.

Each pushing has two stages: first stage in energetic sense – a decisive stage that includes the work of the muscular system, the athlete overturns body weight on the opposite side; the second stage of the pushing – the resultant - changes the direction of the resistances from the impulses received as a displacement or rotation movement. In the case of balance beam, the pushing is somewhat more complex, because it means displacement and rotation in the same time, which is specific to the acrobatic elements (e.g. 11]).

A large number of methodical scientific issues related to the improvement of execution mastery on balance beam are shown in the papers (e.g. [12], [13], [14]–[23]).

The analysis of methodical scientific literature certifies that scientific research and training plans are lacking of concrete tasks on the learning of exercises on balance beam in the basic stages of the multi-annual improvement.

II. MATERIAL AND METHODS

The purpose of the paper is to reveal the kinematic and dynamic characteristics of sports technique key components of the acrobatic elements on balance beam executed by junior gymnasts aged 12 to 15.

Hypothesis of the paper. We believe that the computerized biomechanical video analysis of acrobatic elements on balance beam executed separately, in connection and in mixed way by the junior gymnasts 12 to 15 years old will contribute to the assessment of technical training level in accordance with the specific penalties of this apparatus and the performances achieved in competition.

This scientific approach entailed the organization of a study conducted from 2012 to 2013 with a group of 15 junior gymnasts aged 12 to 15 years, members of Juniors Olympic team of Izvorani. Biomechanical analysis was made by means of Physics Toolkit program and movement postural orientation method, highlighting the key elements of sports technique on balance beam.

To highlight the biomechanical characteristics of sports technique key components used in the acrobatic elements on balance beam we monitored the contents of the exercises made by junior gymnasts aged 12 to 15 during three national events on balance beam.

Within the structure of the acrobatic elements on beam there were shown and analyzed the postures of movement orientation [12]: in preparatory phase – the launchig posture, in basic phase – multiplication of body posture and in final phase – concluding posture (final position).

The execution of acrobatic elements by junior gymnasts aged 12 to 15, presented in different ways: separately, connected and mixed, were analysed using the specialized program Physics ToolKit in order to point out the kinematic and dynamic characteristics of sports technique key components in acrobatic elements on balance beam

For achieving the biomechanical video analysis it was necessary to test the anthropometric measurements (height for calculating the inertia of rotation), identification of biomechanical parameters of each technical element, determination of the spatial benchmarks for analysis (height of balance beam and origin for each movement analyzed), calibration of video frames depending on movement technical structure.

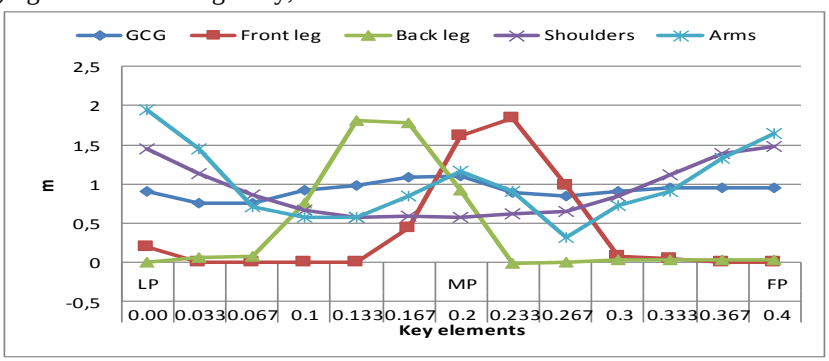
III. RESULTS

Table no. 1 shows the anthropometric data and the parameters necessary for the biomechanical video analysis of junior gymnasts aged 12 to 15 during the execution of acrobatic elements on balance beam in terms of Height, Weight, Inertia of Rotation, Radius of movement of GCG related to toes, joints of shoulders and hands (arms).

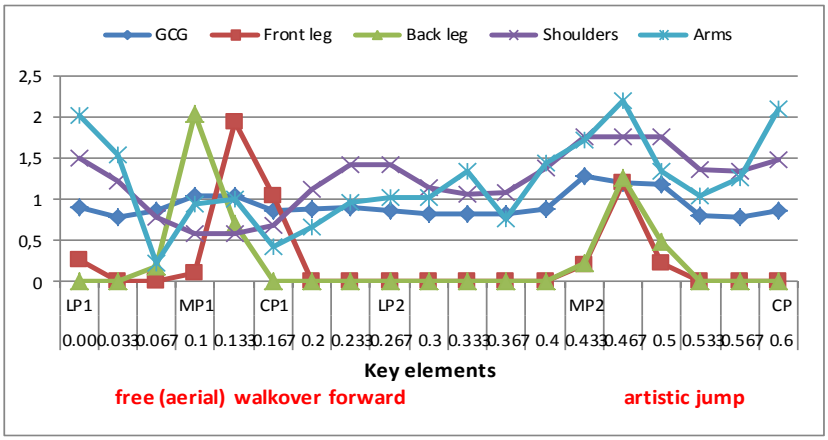
Table 1 Anthropometric data and parameters of biomechanical video analysis of gymnasts 12 -15 years old during execution of acrobatic elements on beam

Statistical indicators	½ body height, arms up, (m)		½ body weight, (kg)		IR, (kg•m^2)		RM / GCG (m)					
							toes		Shoulders		Arms	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
Mean	17.62	16.84	0.944	0.926	15.77	14.52	0.854	0.754	0.485	0.433	0.617	0.481
SD	1.23	1.667	0.03	0.03	2.04	2.35	0.09	0.09	0.06	0.05	0.12	0.09
Cv%	6.98	9.93	3.56	3.56	12.95	16.16	10.49	13.19	13.02	12.17	18.61	18.89
N	5	10	5	10	5	10	5	10	5	10	5	10

Legend: NP – full name; EAL – connected acrobatic elements; IR – inertia of rotation; RM – radius of movement; GCG (hip) –general center of gravity; SD –standard deviation.



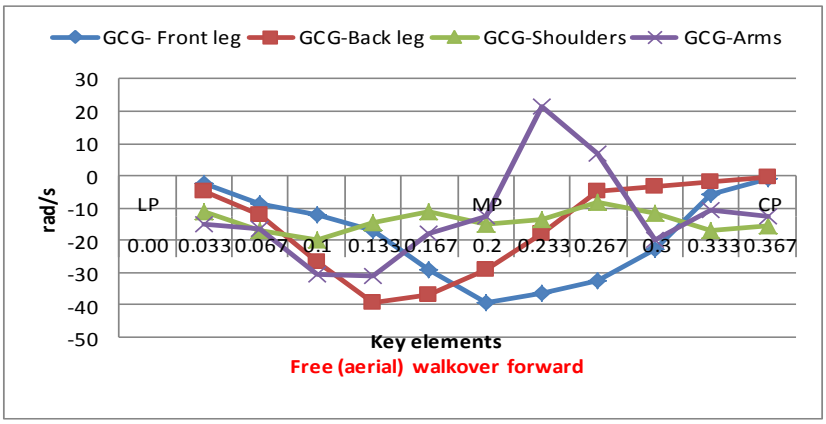
a) Masters National Championship Onești 2012 – separate



b) Masters National Championship Bucharest 2013 – mixed execution

Fig. 1. Trajectories of body segments during execution of free (aerial) walkover forward – vertical displacement Ym, (B.A.)

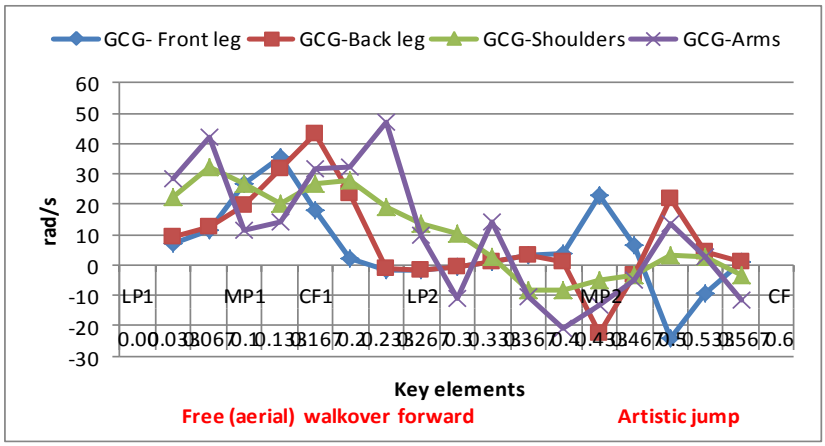
Figure no. 1 (a, b) shows the trajectories of body segments during execution of free (aerial) walkover forward – vertical displacement Ym, performed by the gymnast B.A., in separate execution during Masters National Championship Onești, 2012 and mixed execution during Masters National Championship Bucharest, 2013.



a) Masters National Championship Onești 2012 – separate

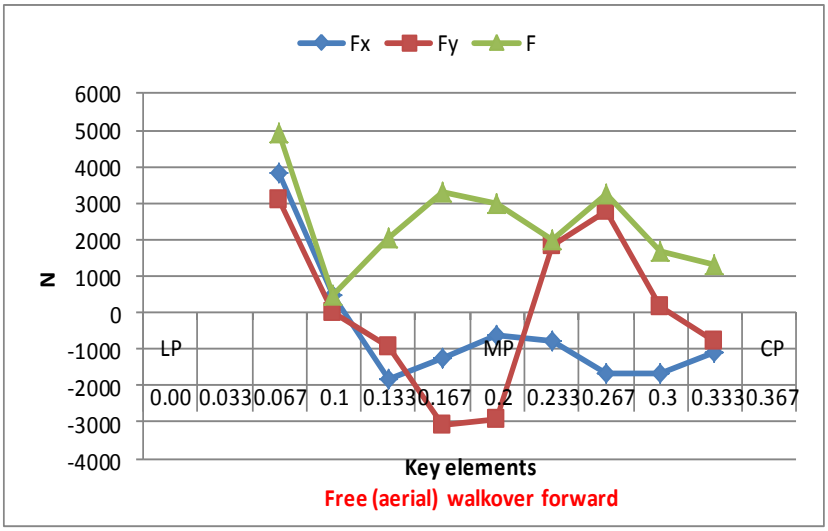
Figure no. 2 (a, b) presents the kinematic characteristics of the angular velocity of body segments during the execution of Free(aerial) walkover forward separate and mixed, performed by gymnast B.A., regarding the relation of GCG with the front leg toes, back leg toes, joint of shoulder and hand (arms) in accordance with the key components of their sports technique.

Figure no. 3 (a, b) presents the dynamic characteristics of force in the execution of Free (aerial) walkover forward, under separate and mixed conditions, performed by gymnast B.A. in accordance with the key elements of sports technique.

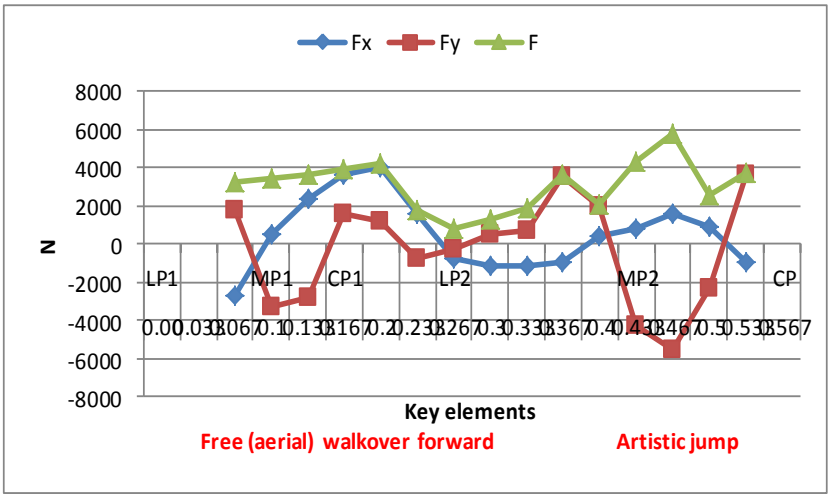


b) Masters National Championship Bucharest 2013 – mixed execution

Fig. 2. Kinematic characteristics of angular velocity of body segments during execution of Free (aerial) walkover forward (B.A.)



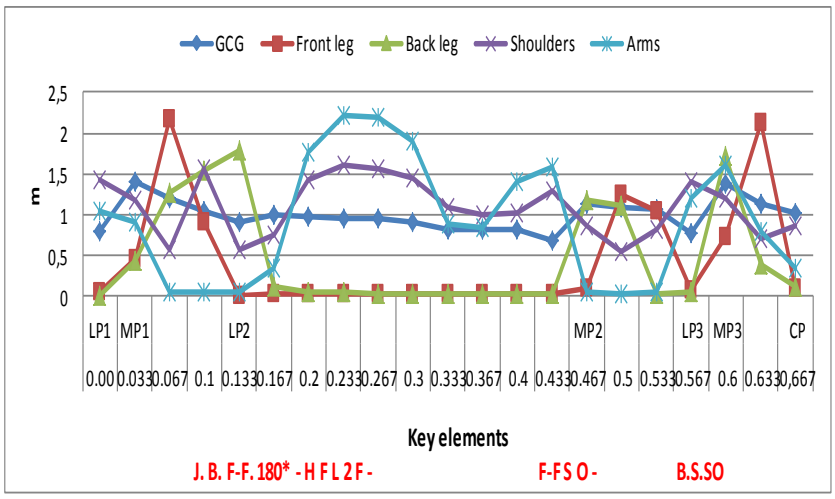
a) Masters National Championship Onești 2012 – separate



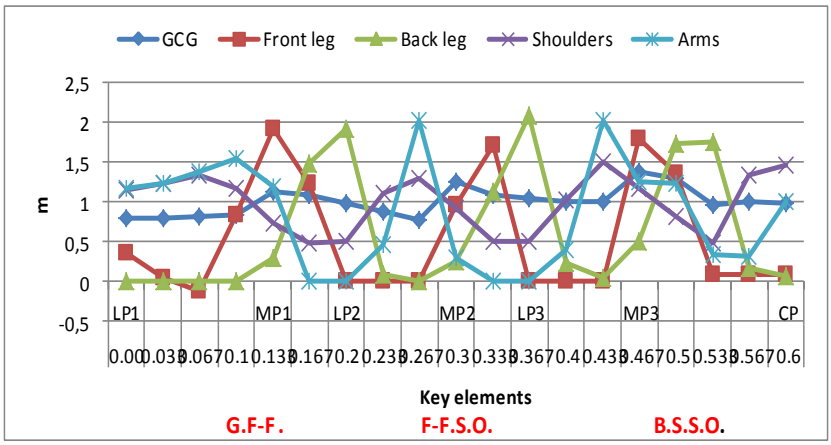
b) Masters National Championship Bucharest 2013 – mixed execution

Fig. 3. Dynamic characteristics of force during execution of Free (aerial) walkover forward (B.A.)

Figure no. 4 (a, b) shows the trajectories of body segments during the execution of acrobatic elements on beam, performed by gymnast B.A., regarding the connection Jump bwd (flic-flac take-off) with ½ twist (180°) to handspring fwd land on 2 feet; F-F.S.O. - Flic-flac with step-out, B.S.S.O. – Salto bwd stretched (step out) (J.B.F-F.180°H.F.L.2 F – F-F.S.O- B.S.S.O) in Masters National Championship Onești 2012 and Gainer flic-flac - Flic-flac with step-out - Salto bwd stretched (step out) (G.F-F- F-F.S.O.- B.S.S.O.) – Masters National Championship Bucharest, 2013.



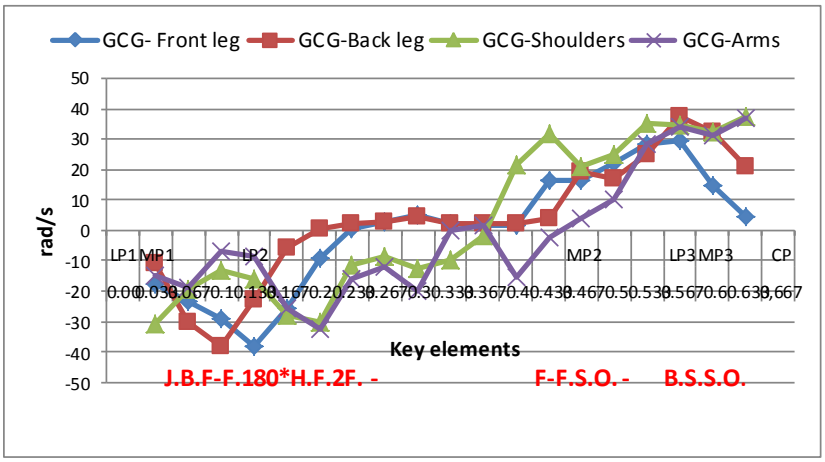
a) J.B.F-F.180°- H.F.L.2F – F-F.S.O- B.S.S.O - Masters National Championship Onești, 2012



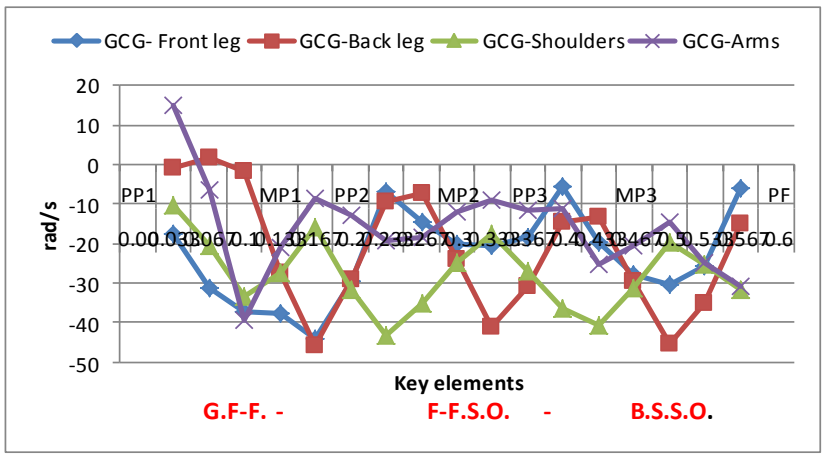
b) G.F-F- F-F.S.O.- B.S.S.O. – Masters National Championship Bucharest, 2013

Note: J.B.F.F.180°-H.F.L2F - Jump bwd (flic-flac take-off) with ½ twist (180°) to handspring fwd land on 2 feet; FFSO - Flic-flac with step-out, B.S.S.O. – Salto bwd stretched (step out); GFF - Gainer flic-flac.

Fig. 4. Trajectories of body segments during the acrobatic elements on balance beam, B.A.



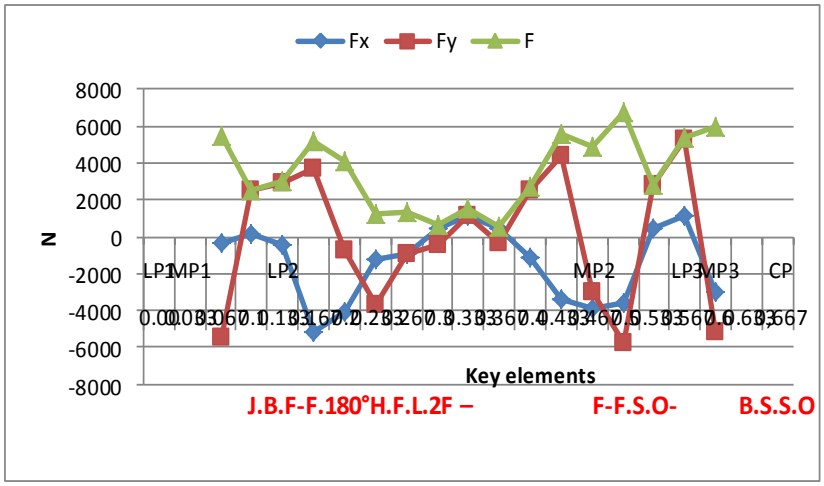
a) J.B.F-F.180°H.F.L.2F – F-F.S.O- B.S.S.O - Masters National Championship Onești, 2012



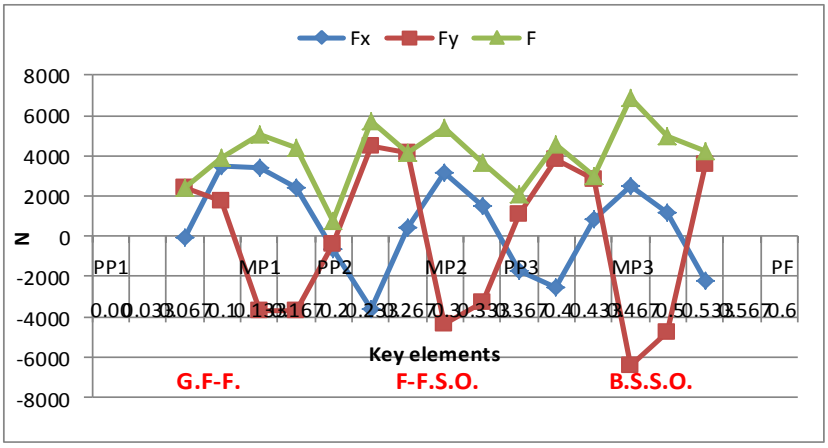
b) G.F-F- F-F.S.O.- B.S.S.O. – Masters National Championship Bucharest, 2013

Fig. 5. Kinematic characteristics of angular velocity of body segments during execution of acrobatic connections on beam, B.A.

Figures no.5 and 6 show the kinematic characteristics of the angular and dynamic velocity of body segments force during execution of acrobatic connections on beam, performed by gymnast B.A., regarding the connection (J.B.F-F.180°H.F.L.2 F – F-F.S.O- B.S.S.O.) - Jump bwd (flic-flac take-off) with ½ twist (180°) to handspring fwd land on 2 feet - Flic-flac with step-out, – Salto bwd stretched (step out) in Masters National Championship Onești 2012 and (G.F-F- F-F.S.O.- B.S.S.O.) – Gainer flic-flac - Flic-flac with step-out - Salto bwd stretched (step out) – Masters National Championship Bucharest, 2013.



a) J.B.F-F.180°H.F.L.2 F –F-F.S.O- B.S.S.O.– Masters National Championship Onești 2012



b) G.F-F- F-F.S.O.- B.S.S.O.– Masters National Championship Bucharest, 2013

Fig. 6. Dynamic characteristics of body segments during execution of acrobatic connections on beam, B.A.

Table 2 shows the sports performances obtained in competitions by the gymnasts aged 12 to 15 in terms of exercises difficulty, execution score and final score during all-around events and the results of apparatus finals.

Table 2. Performances achieved in beam events

Events	Statistical Indicators	Individual all-around, (points)			Apparatus finals, (points)
		D	E	FS	Result
MNC Onești 2012	Mean	5.600	8.554	14.15	14.03
	SEM	0.07	0.15	0.17	0.35
	SD	0.18	0.37	0.43	0.87
	t - SRC			0.38	
	Prob.			0.71; >0.05	
MNC Bucharest 2013	Mean	5.36	8.71	14.06	14.08
	SEM	0.14	0.12	0.18	0.38
	SD	0.53	0.45	0.69	0.94
INCJ Onești 2013	Mean	5.800	8.53	14.33	13.975
	SEM	0.15	0.26	0.35	0.33
	SD	0.47	0.83	1.10	1.06
	t - SRC			1.09	
	Prob.			0.30; >0.05	

Note: MNC – Masters National Championships; INCJ – Individual National Championships for Juniors;
D – difficulty; E – execution; FS –final score; SEM – standard errors mean, SD – standard deviation, t – SRC - Spearman Rank Correlation; Prob. – probability.

IV. DISCUSSIONS AND CONCLUSIONS

The parameters of the biomechanical analysis of acrobatic elements on balance beam highlight gymnasts' average height, body mass, analysis of the acrobatic elements executed separately, in connection of 2-3 acrobatic elements and in mixed series (gymnastic - acrobatic), mean of rotational inertia, mean of movement radius of segments: front leg toes (for pushing), back leg toes (for balance), shoulders and arms (table 1).

The biomechanical video analysis of the acrobatic element free (aerial) walkover forward, executed separately and mixed (fig.1), shows the kinematic spatial-temporal characteristics in terms of trajectories of body segments involved in movement, key components of sports technique, characteristics of the translation movement with rotation around body axis (hip - GCG), characteristics of angular velocity of body segments related to GCG and dynamic characteristics regarding GCG force (Fx, Fy and F).

The results of the performances achieved in the three national competitions highlight the fulfillment of the requirements specific to the category of juniors aged 14 to 15 on balance beam, the mean of the Difficulty scores, the improvement of the Execution score and of the final score in the all-around individual event and the apparatus finals (table no. 2).

The biomechanical video analysis of the acrobatic elements on beam pointed out the kinematic and dynamic characteristics of the key components of sports technique and their influence upon the performances achieved in competition, which confirms the hypothesis proposed.

ACKNOWLEDGEMENT

This case study is part of the pedagogical experiment of the post-doctoral thesis; it is included in the research plan in the field of National University of Physical Education and Sport from Ukraine, with the subject matters: 2.11 (Dynamic static stability as a basis for technical training of those involved in sports gymnastics views), 2.32 (Technical training of qualified athlete based on competitive exercises technique rationalization) and plan of research for 2016 - 2017 of the Faculty of Physical Education and Sport, Ecological University of Bucharest. We express our gratitude to the Romanian Gymnastics Federation and especially to Missis Anca Grigoraș Mihailescu, federal coach and to the coaches of the Olympic Team of Izvorani, who helped us to conduct this research.

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