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A biomechanical analysis of the acrobatic elements on the beam at the level of junior gymnasts 12-14 years old
Analiza biomecanică a elementelor acrobatice la bârnă la nivelul gimnastelor junioare de 12-14 ani

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Abstract

Background. The scientific argument is the highlighting of the kinematic and dynamic characteristics of the key components of sports technique on the beam, which, by computerized video biomechanical analysis, contributes to the establishment of the technical training level and methodological guidelines for the improvement of the technical execution.

Aims. The aim of this paper is the biomechanical analysis of the acrobatic elements on the beam at the level of junior gymnasts 12 to 14 years old. We consider that a video biomechanical analysis of the acrobatic elements on the beam would highlight the key components of sports technique in conformity with the performances achieved in competition.

Methods. This scientific approach led to the organization of an experimental study in the Deva junior team, applied to a group of 8 gymnasts, 12 to 14 years old. This research used the method of video biomechanical analysis by means of a specialized program named Physics ToolKit, monitoring the key components of sports technique of the acrobatic elements on the beam. The study was conducted during the period of the Masters National Championships of Oneşti 2012, in which there were monitored and recorded gymnasts' routines on the beam in the all-around event and the finals on this apparatus. The method used for statistical processing was Microsoft Office Excel 2003.

Results. The findings of the study emphasize the kinematic and dynamic characteristics of the acrobatic elements during the competition routines on the beam, freely executed, connected or mixed. In terms of the comparative analysis of the performances obtained in competition and of the biomechanical features of acrobatic elements which are key components in the sports technique on the beam, we pointed out the level of acrobatic training and some methodological guidelines for improving the technical execution.

Conclusions. The biomechanical analysis of the acrobatic elements on the beam highlighted the kinematic and dynamic features of the key components of the sports technique and their influence on the performances achieved in competition.

Key words: biomechanical analysis, beam, performance, sports technique.

Rezumat

Premize. Evidenţierea caracteristicilor cinematice şi dinamice ale componentelor cheie ale tehnicii sportive la bârnă, prin analiza video biomecanică computerizată, contribuie la constatarea nivelului pregătirii tehnice şi orientării metodologice de îmbunătăţire a execuţiei tehnice.

Obiective. Scopul lucrării este analiza biomecanică a elementelor acrobatice la bârnă, la nivelul gimnastelor junioare de 12-14 ani. Pentru aceasta am considerat că efectuarea analizei video biomecanice a elementelor acrobatice la bârnă va evidenţia componentele cheie ale tehnicii sportive, în concordanţă cu performanţele obţinute în concurs.

Metode. Acest demers ştiinţific a condus la organizarea unui studiu experimental constatativ în cadrul lotului de junioare de la Deva, aplicat unui grup de 8 gimnaste, de vârstă cuprinsă între 12-14 ani. În cercetare s-a folosit metoda analizei video biomecanice, cu ajutorul unui program specializat Physics ToolKit, urmărind componentele cheie ale tehnicii sportive pentru elementele acrobatice la bârnă. Studiul s-a realizat în perioada desfăşurării Campionatului Naţional de Maestre, Oneşti, 2012, unde s-au urmărit şi înregistrat evoluţiile gimnastelor la bârnă, în cadrul competiţiei la individual compus şi finala la acest aparat. Metoda de prelucrare statistică a fost Microsoft Office Excel 2003.

Rezultate. Rezultatele studiului scot în evidenţă caracteristicile cinematice şi dinamice ale elementelor acrobatice în cadrul exerciţiilor de concurs la bârnă, executate liber, în legare sau mixt. Analiza comparativă a performanţelor obţinute în concurs, cu caracteristicile biomecanice ale componentelor cheie ale tehnicii sportive ale elementelor acrobatice la bârnă, scoate în evidenţă nivelul pregătirii acrobatice şi orientării metodologice de îmbunătăţire a execuţiei tehnice.

Concluzii. Efectuarea analizei video biomecanice a elementelor acrobatice la bârnă, a evidenţiat caracteristicile cinematice şi dinamice ale componentelor cheie ale tehnicii sportive şi influenţa acestora asupra performanţelor obţinute în concurs.

Cuvinte cheie: analiza biomecanică, bârna, performanţă, tehnica sportivă.

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Introduction

Artistic gymnastics has made outstanding progress, developing in accordance with the tendencies of high performance sport, but it also has its specific particulars, such as: increase of sports mastery, development and rivalry of competitive program complexity, processing of new routines, etc. (Vieru, 1997; Arkaev & Suchilin, 2004).

The specific features of each artistic gymnastics event are given by the structure and number of technical elements, by the complexity, originality, spectacular character materialized in the maximum effectiveness reached in competition (Niculescu, 2003). Thus, the technique is represented by a system of specific motor structures rationally and economically built, in order to obtain maximum efficiency in competition. The analysis of technique highlights the following components: *technical elements, technical procedure, style and basic mechanism* (Dragnea & Mate-Teodorescu, 2002). In gymnastics, the role of technical training is very important and in close interdependence with the other components; thus, the poor physical training of gymnasts leads to an inadequate technique, and consequently, to lack of success in competition. Also, good technical training based on good physical training, but in the absence of adequate psychological training, results in poor performance (Grigore, 2001).

Due to the impetuous dynamics of gymnastics competition, the number of technical elements created by the great male and female champions who have imposed themselves over time has increased considerably, some of these elements taking over, besides their coded names reflecting their biomechanical features, the name of those who have created and executed them with unique virtuosity (for example, the elements ”Endo”, ”Tsukahara”, ”Comăneci”, ”Korbut”, etc.) (Nicu, 1993).

Research and practice show that the efficiency of learning complex gymnastics elements is increased if the phasic structure of the elements is checked during the process of technical training. In line with this, the periods of movement with or without support can be identified in the technical structure of gymnastics routines (Arkaev & Suchilin, 2004). Several criteria can be used for splitting gymnastics elements into parts, such as pedagogical, psychological, physiological, biomechanical criteria, etc. The increase of the objectification level goes from the pedagogical criteria towards the biomechanical ones. This is why biomechanical criteria are used for dividing gymnastics elements into parts. Thus, the technical structure of gymnastics elements contains three levels – *periods, stages and phases* (Suchilin, 2010).

The beam, a specific event of women’s artistic gymnastics, can be characterized as a balance apparatus par excellence both physically and mentally. From a biomechanical point of view, the mastery and adjustment of balance throughout the exercises on the beam can be achieved by respecting the logical principle of the permanent projection of the center of gravity of the body on the narrow supporting surface. In conformity with the international regulations, the routine on the beam must include a mount, elements of different structural groups (acrobatic, gymnastic, mixed elements) and elements near the balance beam. The whole combination must be characterized by dynamism, changes of rhythm and continuity. The end of the exercise (the dismount) must be consistent with the difficulty of the whole and with the specific requirements of the competition. The dismount off the beam is also a very important moment of each exercise, because the last impression depends on it (Vieru, 1997).

The artistic performance on the beam is acknowledged when the gymnast demonstrates her abilities to transform the routine from a well-structured composition into a performance consisting of a ”whole” that gathers creativity, confidence, personal style and perfect technique (***, 2013).

The location of the support segments or, in other words, the location of the arms and feet on the apparatus, is an important technical element of the movements on the beam. Various exercises, of course, require various supports. Taking into account a work order with the soles in longitudinal standing position, we can point out the symmetrical and asymmetrical position of the feet. The technical rules highlight that the own power is maintained during support on feet, but also during support on hands. There are also several variants of putting the hands on the beam, some of them used for the execution of many static and dynamic exercises - symmetrical position; but the asymmetrical position too enables a good position on the apparatus (Gaverdovskij, 2002).

Regarding the biomechanical particulars and features on the beam, there are some moments that should be highlighted: the role of posture and muscle tone to maintain the balance – one of the main conditions of the gymnast’s rational working posture, especially from the standing up position, from which the major part of the elements on the beam are performed; the technical elements with static balance and the technical elements with dynamic balance (Smolevskij & Gaverdovskij, 1999).

As for the pushes from the standing - start position, these are performed in the ”support – athletic system”, presenting complex biomechanical features of motor movement, where the technical details are introduced by many specialists throughout the training and improvement process. In the case of the beam, the push is a little more complex because it involves displacement and rotation at the same time, specific to acrobatic elements (Gaverdovskij, 2007).

Biomechanical research in artistic gymnastics can be performed using both biomechanical methods and methods taken from other fields of knowledge (pedagogical, mechanical, physiological, psychological, medical, etc.), mainly intended to highlight the features of movement on various apparatus by selecting the data recording, processing and analysis means (Potop, 2007).

Numerous studies are scientifically applied for understanding and classifying movement in gymnastics from a biomechanical point of view, based on a clear establishment of the study field. The most recent classification of movements in gymnastics was made by

Bruggmann (1994) and taken over from Hochmuth & Marthold 1987, quoted by Creţu et al., 2004; this divides gymnastics movements into the following categories:

a) releases and repulsions from solid and elastic surfaces – floor, vaults, balance beam, parallel bars, uneven bars, high bar;

b) vertical revolutions around a fixed or movable axis located in horizontal plane – high bar, uneven bars, still rings;

c) horizontal revolutions around a vertical axis – circular motions on the pommel horse, parallel bars and floor;

d) free flight revolutions – floor, simple and double vaults, twisting vaults, elements of release and grip of the high bar and uneven bars: dismounts off the high bar, uneven bars and still rings;

e) landings – dismounts off all apparatus and difficult elements on the floor and balance beam.

In the case of the balance beam, current concerns in the scientific research on biomechanical aspects have been expressed by Brown, Witten, Espinoza (1995) (quoted by Creţu et al., 2004), referring to the reaction force and simple dismounts, while the biomechanics of acrobatics on the beam and on floor in terms of the optimal angle and velocity of the flip and also, the angular momentum in somersaults is studied by Knoll (1996) (quoted by Creţu et al., 2004).

The aim of the paper is the biomechanical analysis of the acrobatic elements on the beam at the level of junior gymnasts 12 to 14 years old.

Hypothesis

We believe that the computerized video biomechanical analysis of the acrobatic elements on the beam in the case of the 12 to 14-year-old female gymnasts will contribute to the establishment of the technical training level in accordance with the specific penalties on apparatus and the performance achieved in competitions.

Material and methods

An experimental study was conducted in the Deva junior team, applied to a group of 8 female gymnasts, aged 12 to 14 years. This research used the video biomechanical analysis method, monitoring the key components of sports technique of the acrobatic elements on the beam; statistical processing was performed using the Microsoft Office Excel 2003 method. The study was conducted during the period of the Masters National Championships of Oneşti 2012, in which the gymnasts' routines on the beam in the all-around event and the finals on this apparatus were monitored and recorded.

Research protocol

a) *Period and place of the research*

The research was conducted from 16th November to 18th November 2012 throughout the Masters National Championships, at the Sports Hall of Oneşti.

b) *Subjects and groups*

In order to emphasize the biomechanical features of the key acrobatic elements on the beam, we monitored the contents of the routines performed by the 12 to 14-year-old junior gymnasts during the finals on the beam. Eight junior gymnasts aged 12-14 years, members of the Deva junior team, participated in this study.

c) *Tests applied*

The positions and movement orientation were presented and studied in the structure of the acrobatic elements (Boloban, 1990; Sadovski et al., 2009): *start position*, *body position multiplication and final position*.

For highlighting the kinematic and dynamic characteristics of the key components of sports technique in the case of the acrobatic elements on the beam, we analyzed – by means of the specialized program called Physical ToolKit (***, 2011) – the execution of the acrobatic elements by the 12-14-year-old juniors; these elements were shown in different ways: *separated, connected and mixed*.

In order to perform the video biomechanical analysis, it was necessary to test the anthropometric measurements (hands up height, for calculating rotational inertia; identification of biomechanical parameters for each technical element by the program; establishment of the spatial reference points for analysis (height of the balance beam and origin of each analyzed movement), calibration of video frames depending on the technical structure of the movement.

d) *Statistical processing*

Statistical processing in this research was performed using Microsoft Office Excel 2003, in terms of mean - arithmetic mean, SEM - standard error of the mean, SD - standard deviation, t-SRC - Spearman Rank Correlation.

Results

Table I shows the anthropometric data of 12-14-year-old junior gymnasts and the parameters of biomechanical video analysis during the execution of the separated acrobatic elements on the beam, of 2-3 connected elements and of mixed elements (gymnastic and acrobatic).

Table no. II introduces the kinematic features of the body segment trajectories of gymnast IA, in terms of video sequences – number of frames, movement duration, key elements off sports technique (SP - start position, MP - multiplication of position - flight phase and FP - final position - landing).

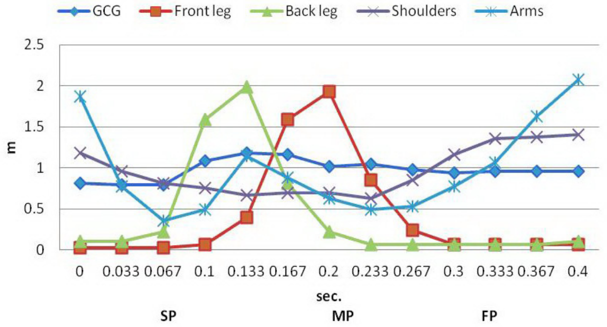

Fig. 1 – Trajectories of body segments during Free (aerial) cartwheel execution – vertical movement (IA).
Legend: GCG-general center of gravity (hip); FL-front leg, BL-back leg, S-shoulders, A-arms.

Figure no. 1 shows the trajectories of the body segments during the performance of Free (aerial) cartwheel - vertical movement (Ym), evidencing the time and the key elements of the execution technique.

Table III shows the results of GCG force and angular velocity in the relationship of GCG with the front leg, back, shoulder and arms (Figures 2 and 3).

Table no. IV shows the results of the performances achieved on the beam in competition, in terms of difficulty, execution, final score and ranking in the finals on apparatus.

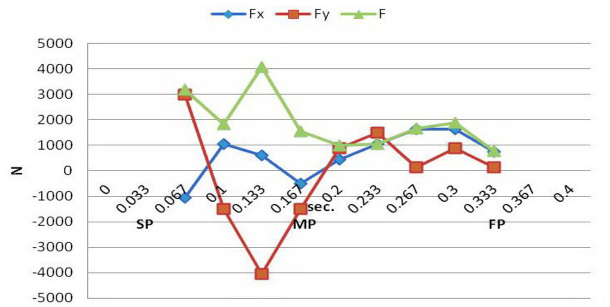

Fig. 2 – Results of GCG force (hip) during execution of Free (aerial) cartwheel - (IA).
Legend: N - Newton.

Table I

Anthropometric data and parameters of biomechanical video analysis of 12-14-year-old gymnasts during performance of acrobatic elements on the beam.

No.	FN	Height (m)	Weight (kg)	Elements: Separated	Elements: CAE	Elements: Mixed	IR kgm^2	CVI (frame)	RM / GCG (m): Front leg	RM / GCG (m): Back leg	RM / GCG (m): Shoulders	RM / GCG (m): Arms
						SL-SBT		5	0.897	0.858	0.491	0.654
1	V.C.	1.49	36.6		FF-SBP		81.25	5	0.984	0.958	0.561	0.919
				FWF				3	0.965	0.98	0.525	0.452
						SL-SST		5	0.904	0.883	0.485	0.726
2	S.S.	1.52	40.4		FF-SBT		93.34	5	0.874	0.851	0.564	0.885
				SFT				3	0.78	0.745	0.559	0.675
						SL-SST		5	0.955	0.937	0.52	0.813
3	T.P.	1.53	38.5		FC-SBSSO		90.12	7	0.92	0.913	0.521	0.874
				FWF				3	1.089	0.994	0.567	0.749
						-		-	-	-	-	-
4	R.M.	1.44	36.9		FF-SBSSO		76.52	3	0.982	1.023	0.552	0.921
				FWF				3	0.935	0.911	0.474	0.689
						-		-	-	-	-	-
5	D.D.	1.47	34.0		FF-SBP		73.47	3	0.818	0.788	0.506	0.793
				FWF				3	0.915	0.896	0.542	0.784
						-		-	-	-	-	-
6	Z.S.	1.45	31.5		FF-SBP		66.23	3	0.84	0.851	0.508	0.757
				FWF				3	0.912	0.93	0.514	0.759
						SL-FC		5	0.963	1.00	0.572	0.903
7	B.A.	1.48	34.1		JB180°WF-FF-SBSSO		74.69	7	0.958	0.984	0.561	0.919
				FWF				3	0.974	0.931	0.541	0.773
						SL-SBSSO		5	0.872	0.838	0.456	0.695
8	I.A.	1.38	32.1		FWF-FF-SBT		61.13	5	0.763	0.764	0.493	0.537
				FC				3	0.915	0.868	0.507	0.746
Mean		1.47	35.5				77.09	4.14	0.915	0.90	0.52	0.76
SEM		0.02	1.10				3.87	0.29	0.02	0.02	0.01	0.03
SD		0.05	3.12				10.9	1.35	0.07	0.08	0.03	0.12

Legend: FN - full name; CAE - connected acrobatic elements; IR - inertia of rotation; RM - radius of movement; CVI - calibration of video image (frame); GCG (hip) - general center of gravity; SL-SST - witch Leap - Salto swd tuked; SL-FAC - Switch Leap - Free (aerial) cartwheel; SL-SBS - Switch Leap - Salto bwd stretched - step out; SFT - Salto fwd tucked to cross stad; FC - Free (aerial) cartwheel; FWF - Free (aerial) walkover fwd; FF-SBP - Flic-flac with step out - Salto bwd piked; FF-SBT - Flic-flac with step out - salto bwd tucked; FC-SBSSO - Free (aerial) cartwheel - salto bwd stretched step out; JB180°WF-FF-SBSSO - Jump bwr (flic-flac take-off) with ½ twist (180*) through hand to walkover fwd - Flic-flac with step out - salto bwd stretched step out; FWF-FF-SBT - Free (aerial) walkover fwd - Flic-flac with step out - salto bwd tucked; SEM - standard error of the mean; SD - standard deviation.

Table II

Results of body segments trajectories during the execution of Free (aerial) cartwheel (IA).

VS (Fr.)	Time (sec.)	KE	CGG (m) x	CGG (m) y	Front leg (m) x	Front leg (m) y	Back leg (m) x	Back leg (m) y	Shoulders (m) x	Shoulders (m) y	Arms (m) x	Arms (m) y
1	0.00	SP	0.73	0.81	0.04	0.02	0.99	0.10	0.39	1.18	0.49	1.87
2	0.033		0.57	0.79	0.04	0.02	0.99	0.10	0.08	0.96	-0.31	0.77
3	0.067		0.41	0.79	0.06	0.02	1.02	0.22	-0.24	0.81	-0.33	0.35
4	0.1		0.10	1.08	0.08	0.06	0.61	1.59	-0.31	0.75	0.00	0.49
5	0.133		-0.06	1.18	0.43	0.39	-0.35	1.99	-0.18	0.67	-0.35	1.14
6	0.167	MP	-0.22	1.16	0.55	1.59	-1.12	0.81	-0.26	0.69	-0.55	0.88
7	0.2		-0.45	1.02	-0.35	1.93	-0.79	0.22	-0.26	0.69	0.12	0.63
8	0.233		-0.61	1.04	-1.46	0.85	-0.69	0.06	-0.24	0.63	-0.63	0.49
9	0.267		-0.77	0.98	-1.18	0.24	-0.69	0.06	-0.28	0.85	-0.49	0.53
10	0.3		-0.85	0.94	-0.99	0.06	-0.69	0.06	-0.45	1.16	-0.10	0.77
11	0.333		-0.87	0.96	-0.99	0.06	-0.69	0.06	-0.51	1.36	-0.08	1.06
12	0.367		-0.87	0.96	-0.99	0.06	-0.69	0.06	-0.63	1.38	-0.12	1.63
13	0.4	FP	-0.87	0.96	-0.99	0.06	-0.83	0.10	-0.71	1.40	-0.39	2.08

Note: x - horizontal movement, y - vertical movement; SP - start position; MP - multiplication of position (flight phase); FP - final position (landing); KE - key element.

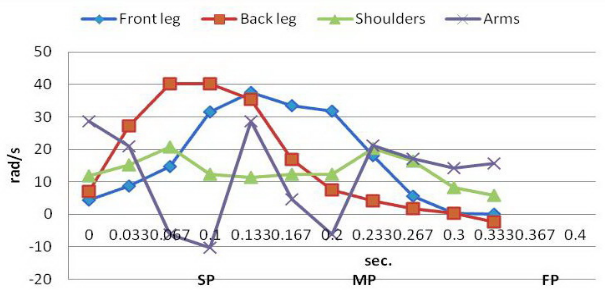

Fig. 3 – Results of angular velocity of body segments during execution of Free (aerial) cartwheel.
Legend: PF - front leg; PS - back leg.

Table IV
Performances achieved in competition on the beam (n=8).

FN	All-around finals			Apparatus	
	D	E	FS	Result	Rank
V.C.	5.300	8.275	13.575	12.750	8
S.S.	5.600	8.525	14.125	14.535	3
T.P.	5.500	8.700	14.200	13.350	6
R.M.	5.200	8.600	13.800	13.950	4
D.D.	5.200	8.925	14.125	12.935	7
Z.S.	5.700	8.650	14.350	13.885	5
B.A.	5.700	9.125	14.825	14.600	2
I.A.	5.800	8.050	13.850	15.050	1
Mean	5.500	8.61	14.11	13.88	
SEM	0.08	0.12	0.13	0.29	
SD	0.24	0.34	0.38	0.82	
t - SRC	0.69 p>0.05				
Probability	0.48				

Note: Mean - arithmetic mean, SEM - standard error of mean, SD - standard deviation, t-SRC - Spearman Rank Correlation; FN - full name, D - difficulty; E - execution, FS - final score, Rank - ranking.

Discussion

The biomechanical analysis of the acrobatic elements on the beam was performed using the Physics ToolKit program, on a group of 8 finalist gymnasts on this apparatus. The study was conducted during the Masters National Championships of Oneşti 2012.

Regarding the content of the routine on the beam for the difficulty value (DV), a maximum number of 8 elements with the highest value were taken into consideration, including the dismount*: maximum 5 acrobatic elements and minimum 3 gymnastic elements*. For the composition requirements, with all amendments performed, the gymnast received 2.5 points, consisting of: 1) one connection of minimum 2 different gymnastic elements out of which 1 hop with legs in 180° split (transversally or laterally) or sideward pike opening; 2) pirouette; 3) an acrobatic series of minimum 2 elements with flight phase out of which 1 somersault (the elements can be identical); 4) acrobatic elements in different directions: forward/ sideward and backward and 5) dismount (***, 2013).

The study results highlight the biomechanical analysis of the key components of sports technique (according to Boloban, 1990), especially the execution of the acrobatic element Free (aerial) cartwheel, in terms of start position (SP), multiplication of position – momentum of maximum height of GCG (MP) and final position – landing.

Regarding the parameters of the biomechanical analysis of acrobatic skills on the beam, we notice a mean of 1.47 m for the gymnasts' height and 35.5 kg for body mass. The following elements were analyzed: 8 acrobatic elements performed separately, 8 connections of 2-3 acrobatic elements and 5 mixed series (gymnastic - acrobatic), having a mean rotational inertia of 77.09 kgm^2 and a mean movement radius of front leg toe segments of 0.915 m, 0.90 m for back leg toes (putting the foot on the beam), 0.52 m for the mean of the shoulders and 0.76 m for the mean of the arms (Table I).

During this study, we carried out a video biomechanical analysis of the acrobatic element, Free (aerial) cartwheel - landing in cross or side position on one or both feet; element of difficulty D -0.4 points – specific composition requirement on the beam.

The video biomechanical analysis highlights the key elements of sports technique specific to the acrobatic element Free (aerial) cartwheel in terms of start position by bending the torso forward, pushing from the front leg and rotation of the arms forward till reaching the maximum height momentum of GCG (first phase), followed by the 2nd phase, with 180° turn and continuing by overturning the back leg (swing), till landing on the opposite side (revolution around the hip) - raising the torso while the front leg touches the beam and the arms are rotated and raised upward in the final position – lunge landing.

In terms of trajectories of the body segments during the execution of Free (aerial) cartwheel element, there

Table III
Results of biomechanical analysis - Free (aerial) cartwheel (IA).

VS (Fr.)	Time (sec.)	KE	GCG (N)			Front leg (rad/s)	Back leg (rad/s)	Shoulders(rad/s)	Arms(rad/s)
			Fx	Fy	F				
1	0.00	PP							
2	0.033					4.49	7.03	11.86	28.68
3	0.067		-1050	3000	3180	8.79	27.32	15.09	20.86
4	0.1		1050	-1500	1830	14.73	40.28	20.70	-6.16
5	0.133	MP	599.53	-4050	4090	31.57	40.32	12.26	-10.32
6	0.167		-499.64	-1500	1560	37.57	35.3	11.33	28.67
7	0.2		449.64	899.29	1010	33.39	16.95	12.42	4.59
8	0.233		1050	1490	1060	31.84	7.57	12.33	-6.18
9	0.267		1650	149.88	1660	18.16	4.05	20.32	21.14
10	0.3		1650	899.28	1880	5.63	1.71	16.41	17.15
11	0.333		749.41	149.88	764.25	0.39	0.27	8.32	14.26
12	0.367					0.00	-2.34	5.82	15.63
13	0.4	PF							

Note: VS-video sequence (frame), KE-key element of movement; Fx-horizontal force; Fy-vertical force; F-resultant of force, N-Newton.

is a maximum height of the GCG of 1.18 m and torso bending with the shoulder at 0.67 m height, which ensures legs rotation around the hip and torso raising in the final position (landing).

Concerning the force at GCG level, we notice that the momentum of maximum height on Fy is – 4050 N, while the highest values are recorded in vertical direction (Ym), which contributes to the performance of somersault rotation with legs apart by a pushing and balancing movement.

As for the results of the angular speed of the body segments involved in the execution of the acrobatic element Free (aerial) cartwheel, we can observe, in the start position by torso bending, a value of 11.86 rad/s, front leg for pushing - 4.49 rad/s, back leg for balance - 7.03 rad/s and arms rotation - 28.68 rad/s – what matters the most is the arms' work, the pushing and the balance of the back leg in the phase of position multiplication at the momentum of the maximum height of the GCG [t-1.333sec.]- the front leg has a value of 31.57 rad/s, the back leg – 40.32 rad/s, shoulders – 12.26 rad/s and arms – 10.32 rad/s; in the phase of the final position [t-0.367sec], before landing fixation, the angular velocity values are the following: the balance leg moves for counterbalancing the position – (-2.34 rad./s), the velocity of torso raising decreases up to - 5.82 rad/s, while the raising of the arms – 15.63 rad/s.

Regarding the performances achieved during the Masters National Championship, all the 8 gymnasts who participated in the all-around event were qualified in the finals on apparatus (all these gymnasts were members of the junior team that used to train in Deva; at the present moment they are training in the Olympic National Center of Izvorani).

In terms of the content of the routines on the beam, all gymnasts performed all the amendments of the requirements for the junior class 12 to 14 years old, having a mean difficulty score of 5.500 points (minimum value 5.200 points and maximum value 5.800 points); the mean score for execution was 8.61 points (minimum value 8.275 points and maximum value 9.125 points) and the mean final score was 14.11 points.

Concerning the results achieved in the finals of the beam event, if we compare them with the results of the all-around event, we notice a diminution of the score for execution and of the final score by 0.23 points. The coefficient of correlation between the two competitions shows insignificant values t-0.69 at p>0.05, which does not confirm the influence of the means of the performances between competitions and a poorer performance in the finals on apparatus. However, there are also individual values evidencing an improvement of performance in the finals of the beam event: for example, athlete IA ranked the first starting from the 5th place.

Conclusions

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

The video biomechanical analysis of the acrobatic element Free (aerial) cartwheel highlights the spatial-temporal kinematic features regarding the trajectories of the body segments involved in movement (x, y, R), key-components of sports technique, characteristics of translation movement with revolution around the axis of the body (hip – GCG), features of the angular velocity of the body segments related to GCG and the dynamic features regarding GCG (Fx, Fy and F).

The results of the performances obtained during the Masters National Championship evidence the achievement of the requirements of junior class 12 to 14 years old on the beam, the mean difficulty scores, the diminution of the score for execution and the final mean in the apparatus finals and the improvement of individual performances.

The video biomechanical analysis of the acrobatic elements on the beam emphasizes the kinematic and dynamic characteristics of the key components of sports technique and the influence exerted by these on the performance achieved in competition, which confirms the suggested hypothesis.

Conflicts of interest

There are no conflicts of interests.

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