

Original Article

Biomechanical characteristics of the synchronization of key elements of sport technique of the complex dismounts off beam

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Abstract:

The purpose of this paper is to highlight the biomechanical characteristics of the synchronization of the key elements of sports technique of the complex dismounts movement off beam. This scientific approach has been performed by conducting a comparative study between six senior athletes aged 16 and 18 respectively, components of the national team of artistic gymnastics, finals apparatus, during the Open National Individual Championships, Bucharest, 2014. The following methods were used during the research: bibliographic study, method of observation, method of case study; method of video recording; method of biomechanical study; statistical-mathematical method and graphical representation method. The study results reveal that by using the video method and the method of computerized biomechanical analysis of translational and rotational motion sports technique on balance beam we highlighted the biomechanical characteristics of the synchronization of the key elements of sports technique between the two angles of the motion plane and also comparatively between gymnasts' routines.

ey words: gymnastics, balance beam, biomechanics, dismount, synchronization.

Introduction

Artistic gymnastics currently registered remarkable progresses, characterized by motor coordination, emotional balance, resistance to stress, focused attention, vestibular balance, etc. Balance beam, the third event specific to women's artistic gymnastics, is characterized by balance both physically and mentally. In conformity with the regulations, the exercise on balance beam must include a mount, the content with difficult elements belonging to different structural groups and a dismount (Vieru, 1997; Arkaev, Suchilin, 2004; Potop, 2007, 2014). The dismount is the most important moment of each routine because the last impression depends on it. In the table of difficult elements on balance beam included in the Code of Points (FIG, 2013), the dismount is the 6th group of elements and includes 7 types of dismounts, with different values of difficulty (A, B, C, D, E, F and G).

The studies of some researchers who promote the video computerized method of biomechanical analysis of sports technique 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 purchase of complete systems or the use of programs and equipment for image analysis based on the same principles for the implementation of this method (Crețu, Simăn, Bărbulescu, 2004).

In terms of technical bases of gymnastics routines, these ones can be divided into the following groups: *postures, force movements, balance movements and static exercises*. Postures are phases to start or to finish a motion. In the specialized literature there is an analysis method of sports technique, namely the method of *postural orientation of the movement*, according to Professor V. Boloban (2013), in which there are well shown the key elements of gymnastics exercises, especially the acrobatic ones, with complex coordination. The review of specialized literature certifies about the importance of the research on gymnastics exercises technique and its learning, taking into accounts the body postures and positions (Bradshaw, Rossignol, 2004; Sadovski, Boloban, Nizhnikovski, Mastalezh, 2009; Pidcoe, McPherson, 2009; Potop, Carmen, Andreyeva, 2014; Potop, Grigore, Marinescu, Boloban, 2014, etc.).

Biomechanics has been defined as "the application of physics laws of motion to the study of biological systems" (Burdett, 1983). Measurements for motion quantification resulted from three specific sources (Thomas, Nelson, 1997): high-speed cinematography, force transducers and electromyogram.

At the present moment, the biomechanical analysis had an extraordinary development, allowing the almost instantaneous display of the variations in time and space of the postures, distances, time speeds, even the accelerations and forces. The image acquisition and trajectories processing related to sequences (or frames) is called 2D (two dimensions) or 3D (three dimensions) of biomechanical motions (of sports execution techniques). When the video capture or shooting is made with a single camera, namely in a plane with two dimensions, the

analysis is 2D; when shooting or image capture is made with two cameras located so that the motion is spatially sensed in three dimensions, then the analysis is 3D (Gagea, 2006).

In the field of programming, a *monitor* is a method of synchronizing two or more tasks that use a shared resource, typically a hardware device or a lot of variables (www.ro.wikipedia.org). The communication between cooperating digital systems is governed by a set of standards developed by ISO (International Standard Organization) resulting in the OSI model (Open System Interconnection). The physical model of interconnection of OSI reference model shows the way of communication by data connections - electric interface, communication synchronization, errors correction, routing to other networks, circuits to other networks, presentation by display, formatting, editing and application. Time is an important dimension in data transfer case too. There are two modes to carry out a transfer in terms of time: *synchronous* (transmitter and receiver use the same clock); *asynchronous* (transmitter and receiver use different clocks) (<http://www.vega.unitbv.ro/~ogrutan/ti/cap1.pdf>).

The purpose of this paper is to highlight the synchronization of the video frames of sports technique of the complex dismounts movement, specific the translational and rotational motion on balance beam.

Hypothesis of the work. We believe that by using the video method and the method of computerized biomechanical analysis of complex dismounts movement, specific characteristics of the translational and rotational motion on balance beam we shall highlight the synchronization of key elements of sports technique between the two angles of the motion plane and also comparatively between gymnasts' routines.

Material & methods

This scientific approach was made by conducting a comparative study between six athletes aged 16 and 18 respectively, members of the national team of artistic gymnastics, during the Open National Individual Championships, Bucharest, 2014. The following methods were used during the research: bibliographic study, method of observation, method of case study; method of video recording by means of two Panasonic cameras - Mini DV and JVC, shooting in two angles of the motion (perpendicular to motion plane and 30° on motion plane) and the Pinnacle Studio program of capture and conversion of image from analog format into AVI format with 30 frames per second; the method of biomechanical study was applied by means of Kinovea programs to achieve the synchronization of images with two windows and the Physics Toolkit program for processing the kinematic and dynamic characteristics of the complex dismounts movement with back layout somersault with 720°, 900° and 1080° turn, double back tucked and piked somersault executed from back flip on 1 foot and back flip (FF), from round-off somersault (RS) and from round-off, back flip (RF); statistical-mathematical method by means of KyPlot program and graphical representation method - Excel and Corel.

For the biomechanical analysis of the dismounts off the balance beam, it has been chosen as reference the height of the apparatus, namely 1,20 m, while the origin is the distal end of the balance beam. The calibration of images (frames) was 3 frames at each step of advancement.

Results

The processing of the video capture and the transformation into AVI movies have been performed by means of Pinnacle Studio program; it has been also used the Physics Toolkit program of biomechanical analysis, regarding the anthropometric and biomechanical indicators necessary for the analysis of the dismounts off balance beam (translational and rotational motion) (table no. 1).

Table 1. Anthropometric and biomechanical indicators necessary for the biomechanical analysis of the complex dismounts movement off beam (n = 6)

Full name	Dismount	W. (kg)	HwAU (m)	I.R. (kgm ²)	R.M.(m)					
					Toes		Shoulders		Arms	
					bf	ff	Left	Right	Left	Right
IA	BLS720°	34,6	1,80	110,16	0,739	0,721	0,398	0,404	0,509	0,431
IL	BLS1080°	45,1	1,93	167,99	0,766	0,769	0,416	0,410	0,534	0,549
MA	BLS1080°	37,9	1,88	133,95	0,756	0,722	0,436	0,425	0,476	0,533
OA-M	BPDS	41,6	1,94	156,57	0,733	0,730	0,406	0,398	0,383	0,382
P.A.	BLS720	30,6	1,84	103,59	0,653	0,654	0,446	0,449	0,608	0,582
S.A.	BKDS	34,4	1,81	112,69	0,594	0,595	0,386	0,367	0,427	0,426
Mean		37,37	1,87	130,83	0,71	0,70	0,41	0,41	0,49	0,48
SEM		2,16	0,02	10,88	0,03	0,03	0,01	0,01	0,03	0,03

Note: W. – weight, HwAU – height with arms up, I.R. – inertia of rotation, R.M. – radius of segments movement, bf – back foot; ff – front foot; Mean – arithmetical mean, SEM – standard error of the mean.

Figures 1 and 2 shows the synchronization of the key elements of sports technique used in the dismount off the balance beam, by means of Kinovea program, from two angles of the motion plane and the comparative analysis of the dismounts performed by the two gymnasts.



Fig. 1. Synchronization of video images of sports technique key elements of the back layout somersault with 1080° turn dismount off beam from 2 angles of the motion plane, gymnast - I.L.



a) FF-BLS1080°- M.A.

b) R-BF-BLS1080°- I.L.

Fig. 2. Synchronization of video images of sports technique key elements of the back layout somersault with 1080° turn dismount off beam perpendicular on motion plane

Note: back flip on 1 foot and back flip - back layout somersault (FF-BLS1080°); round-off, back flip - back layout somersault (RFBLS1080°)

Table 2. Results of spatial-temporal characteristics of the synchronization of video frames of the sports technique key elements of the complex dismounts movement off beam (n=6)

Key element	Ind. Statist.	Times, sec	GCG (m)			Toes (m)					
						bf			ff		
			X	Y1	Y2	X	Y1	Y2	X	Y1	Y2
LP	Mean	0,067	-0,429	0,926	0,756	-0,232	0,107	0,08	-0,447	0,072	0,047
	SEM	0,00	0,07	0,03	0,12	0,07	0,01	0,01	0,05	0,02	0,02
MP, FMH	Mean	0,167	0,141	1,439	1,441	-0,016	1,572	1,503	0,015	1,576	1,537
	SEM	0,01	0,08	0,06	0,06	0,24	0,18	0,15	0,26	0,18	0,16
CP	Mean	0,372	1,537	-0,405	-0,334	1,512	-0,951	-0,846	1,579	-0,91	-0,845
	SEM	0,01	0,04	0,02	0,01	0,07	0,02	0,01	0,06	0,01	0,01

Table 3. Continuation of table 2

Key element	Ind. Statist.	Times, sec	Shoulders (m)						Arms (m)					
			Left			Right			Left			Right		
			X	Y1	Y2	X	Y1	Y2	X	Y1	Y2	X	Y1	Y2
LP	Mean	0,067	-0,256	1,387	1,216	-0,203	1,393	1,362	-0,312	1,698	1,612	-0,198	1,609	1,697
	SEM	0,00	0,09	0,04	0,11	0,09	0,04	0,06	0,09	0,07	0,07	0,17	0,06	0,06
MP, FMH	Mean	0,167	0,325	1,155	1,107	0,351	1,164	1,152	0,452	1,267	1,177	0,402	1,245	1,168
	SEM	0,01	0,11	0,09	0,09	0,12	0,09	0,08	0,06	0,11	0,09	0,06	0,11	0,10
CP	Mean	0,372	1,312	-0,149	-0,065	1,280	-0,147	-0,189	1,269	-0,413	-0,343	1,238	-0,421	-0,354
	SEM	0,01	0,07	0,07	0,06	0,04	0,05	0,09	0,11	0,06	0,09	0,09	0,09	0,05

Note related to tables no. 2 and 3: X – horizontal displacement, Y1 – vertical displacement; (X, Y1) – perpendicular on plane of motion; Y2 - vertical displacement 30° on plane of motion; GCG – General centre of

gravity (hips); LP – launching posture after taking off from back flip, MP – multiplication of body posture; FMH - flight maximum height of GCG; CP – concluding posture – landing.

Tables 2 and 3 shows the results of spatial-temporal characteristics of the synchronization of video frames of the sports technique key elements of the complex dismounts movement off beam, in horizontal displacement (X) and vertical one (Y1) – perpendicular to the motion plane and vertical displacement (Y2) – in 30° angle on motion plane.

Table 4. Results of angular velocity and of body segments force of sports technique key elements of the complex dismounts movement off beam (n=6)

Key elements	Indic. Statist.	GCG (N)			Toes - GCG (rad/s)		Shoulders - GCG (rad/s)		Arms – GCG (rad/s)	
		Fx	Fy	F	bwd	fwd	Left	Right	Left	Right
LP	Mean	1227,08	3628,14	4031,67	-14,13	-10,54	-28,11	-27,32	-32,32	-30,6
	SEM	254,97	861,79	700,67	1,86	1,86	1,45	1,72	3,99	3,19
MP, FMH	Mean	1626,27	-	-	-	-28,59	-	-	-	-23,12
	SEM	570,94	5818,33	6155	-28,32	-	-26,37	-27,89	-19,94	-
CP	Mean	-1808	7241,67	7546,67	-7,38	-7,82	-5,38	-7,27	-1,39	-3,68
	SEM	542,41	527,34	573,19	1,54	1,14	2,17	0,92	3,23	4,05

Note: tables 1 and 2; Fx - horizontal of force; Fy – vertical of force; F – resultant of force.

Table 4 shows the results of angular velocity of body segments in terms of relationship of GCG and back foot toes, front foot toes, shoulders and arms and the horizontal, vertical and resultant of force of GCG displacement during the execution of complex dismounts movement on beam, under the conditions of the Open National Championships of Artistic Gymnastics, final apparatus, Bucharest 2014.

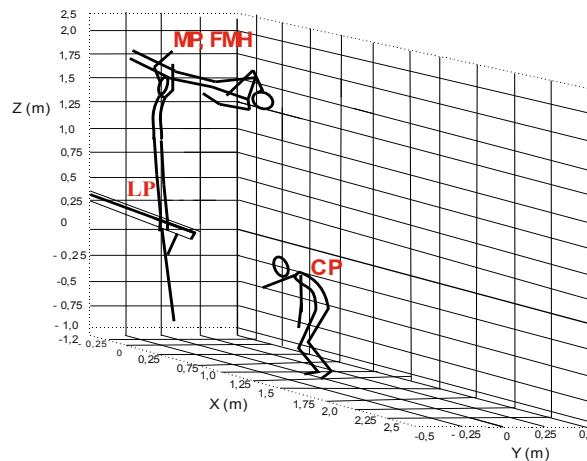


Fig. 3. 3D representation of back layout somersault with 1080° turn dismount off beam, gymnast I.L.

Table 5. Angular characteristics of synchronization of video frames of sports technique key elements of the complex dismounts movement off beam by Kinovea program

Full Name	Dismount	LP	CP
		(degrees)	(degrees)
IA	BS720°	219	134
I.L.	BS1080°	193	149
MA	BS1080°	201	139
OA-M	DBPS°	203	100
P.A.	BS720°	222	147
S.A.	BDTS°	206	126
	Mean	207,33	132,5
	SEM	4,53	7,36
		9,07; P<0,001	

Note: LP - body launching posture – moment of detachment at the end of the beam; CP - concluding position of the body – landing.

Table no 5 shows angular characteristics of body segments of the key elements of sports technique in the dismounts off beam and significant differences regarding comparison between the means of the LP and CP at $P < 0,001$.

Discussions

The introduction of the anthropometric data and the calculation of the biomechanical indicators necessary for the biomechanical analysis of the complex dismounts movement off the balance beam reveal an average weight of 37,37 kg and a mean of 1,87 m of the height with arms up; the rotational inertia is 130,83 kgm^2 . Regarding the motion radius related to body segments during the execution of the dismounts off the balance beam, we notice a mean of 0,71 m at the back foot and 0,70 m – front foot; left shoulder – 0,41 m, right shoulder – 0,41 m; at left arm level, the mean is 0,49 m and 0,48 m at the right arm (table no. 1).

The video analysis of the synchronization of sports technique key elements of the back layout somersault with 1080° turn dismount off beam, made by means of Kinovea program highlights the following matters: at the launching posture (PP) there is a difference between the take-off angle 92° and 95° and there is a specific location of the feet before the hurdle onto the beam, a slight desynchronization in the basic phase of the multiplication of body posture – the maximum height of GCG is higher at I.L., performing a rotational motion in the two axes of the body (transverse – somersault and longitudinal – twisting, 3/1 twist); a desynchronization of the landing time and an incomplete rotation occur at the landing (fig.2).

The results of the spatial-temporal characteristics of the synchronization of sports technique key elements of the back layout somersault with 720°, 900°, 1080° turn, double back tucked and piked somersault dismounts off beam reveal close values of the kinematic characteristics of body segments in horizontal displacement (X1m) and vertical one (Y1m) – perpendicular to the motion plane and vertical displacement (Y2m) – in 30° angle on motion plane (tables no. 2 and 3).

Regarding the kinematic characteristics of the angular velocity of body segments during the dismounts off beam, one can notice an increase of the angular velocity more obvious at arms level during the phase before flipping off the beam LP of -30,6 – (-32,32) rad/sec; in MP phase, in FMH an angular velocity of -28,32 – (-28,59) rad/sec at toes level R720° and shoulders and toes in FF double back piked dismount and in CP – landing – a velocity of -7,38 – (-7,82) rad/sec at arms level in both dismounts (table 4).

As for the dynamic characteristics of the moment of force resultant of body GCG, one can notice the effect of rotation of the force during the dismounts analyzed in both competitions: in LP phase – we notice a value F_x - 1227,08 N, F_y - 3628,14 N and F - 4031,67 N, in MP phase FMH – F_x - 1626,27 N, F_y - 5818,33 N and F - 6155 N and in CP phase – landing of F_x - (-1808N), 7241,67 N and F - 7546,67 N (table 4).

The graphical representation 3D of the back layout somersault with 1080° turn dismount off beam showed the synchronization of planes, body axes and motion dimensions of the key elements of sports technique (fig. 3).

The video analysis of the synchronization of sports technique key elements of the complex dismounts movement off beam, made by means of Kinovea program highlights the following matters: at the launching posture (LP) there is a difference between the take-off angle has a mean of 207,33° and there is a specific location of the feet before the hurdle onto the beam, a slight desynchronization in the basic phase of the multiplication of body posture – the maximum height of GCG, performing a rotational motion in the two axes of the body (transverse – somersault and longitudinal – twisting, 3/1 twist); a desynchronization of the landing time, angular position has a mean of 132,5° and an incomplete rotation occur at the landing (table 5).

Conclusions

The video computerized analysis allowed the identification of the key elements of sports technique of the complex dismounts movement off beam in accordance with motion planes.

There were highlighted the spatial and temporal characteristics of the synchronization of sports technique key elements compliant with the motion planes.

The use of the video method and the method of computerized biomechanical analysis of complex dismounts movement, specific characteristics of the translational and rotational motion on balance beam revealed the synchronization of key elements of sports technique between the two angles of the motion plane and also comparatively between gymnasts' routines.

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