Original Article

Biomechanical characteristics of the dismounts off beam of junior gymnasts 12 -15 years old

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Abstract:

This paper aims to highlight the biomechanical characteristics of the dismounts off beam in women's artistic gymnastics. This scientific approach has led to a study carried out throughout the period of two national competitions 2012 and 2013, with a group of 13 junior gymnasts aged 12 to 15, members of the Junior Olympic team of Izvorani. The biomechanical analysis has been performed using Kinovea and Physics Toolkit programs and the method of postural orientation of the movement, highlighting the key elements of sports technique in the dismounts off beam. The results of the study showed the anthropometric and biomechanical indicators necessary for the biomechanical analysis of the dismounts off beam in the case of junior 12 to 15 years old. The comparative biomechanical analysis of the dismount off the beam highlighted the influence of the kinematic and dynamic characteristics on the technical execution in accordance with the performances achieved in competitions.

Key words: Artistic gymnastics, biomechanics, dismount, beam, performance.

Introduction

Artistic gymnastics has recorded remarkable progresses, highlighting the fact that it develops in accordance with the trends of performance sport, but it has its specific features too, such as: 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 (Vieru, 1997; Arkaev, Suchilin, 2004).

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 element, technical procedure, style and basic mechanism* (Dragnea, Mate – Teodorescu, 2002). The effective learning, in different stages of technical training, can be provided only if the learning stages and their content are closely related to efficiency criteria (Platonov, 2004). Analyzing the technique of gymnastics exercises, in terms of bio-mechanical positions, the "arithmetical" entry is used, involving operations of improvement of the concrete matters (Smolevskij, Gaverdovskij, 1999).

In gymnastics, the role of the technical training is very important and in close interdependence with the other components; so, a poor physical training of the gymnasts leads to a bad, wrong technique, thus to lack of success in competition. Also, a good technical training based on a good physical training, but in the absence of an adequate psychological training, results in poor performances (Grigore, 2001).

The beam, specific event of women's artistic gymnastics, can be characterized as a balance apparatus par excellence both physically and mentally. From biomechanical point of view, the mastery and adjustment of balance throughout the exercises on beam can be achieved by respecting the law principle of the permanent projection of body center of gravity on the support surface so narrow (Vieru, 1997).

In conformity with the international regulations, the routine on 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 (dismount) must be consistent with the difficulty of the whole and 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, Potop, 2014).

The location of the support segments or, easier said, the location of arms and feet on the apparatus, are important technical elements of the movements on beam. Various exercises, of course, require a different support. Taking into account a work order with the soles location in longitudinal standing position, we can point

out the following matters: symmetrical and asymmetrical position of the feet. The third position is common in the execution of the jump "from tempo", in a "round-off –flick" connection, "flick-jump" and so on. In biomechanical terms, these working positions are worse for the detachment than the symmetrical position (Gavardovskij, 2002).

The technical rules highlight that the own power is maintained during the support on feet, but also during the support on hands. 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 -symmetrical position; but the asymmetrical position too enables a good position on the apparatus (Gavardovskij, 2002).

Gymnastics exercises of detachment-strain type are well presented by Gavardovskij (2007) in terms of energy mainly. In the basic dynamic notions, any detachment from the beam is formed of the double phase of the movement. The first phase in energetic sense – crucial: includes the active part, of strengthening the muscular work. The athlete pushes the body weight on the opposite side, where the force F , acting on the segments submitted to the support, balance the reaction of the support N , the peripheral connections receive the movement in the opposite part of the movement; the second phase of the detachment – the resultant, changes the direction of the efforts – which tends to draw together the muscular connections of balance and support (Gavardovskij, 2007).

"Biomechanical researches in artistic gymnastics can be performed using both biomechanical methods and 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" (Potop, 2007, p. 140).

Several criteria can be used for splitting gymnastics elements into parts, such as pedagogical, psychological, physiological, biomechanical criteria, etc. The increase of objectification level goes from the pedagogical criteria towards the biomechanical ones. That is why the biomechanical criteria are used for dividing the gymnastics elements into parts. Thus, the technical structure of gymnastics elements contains three levels – *periods, stages and phases* (Suchilin, 2010).

In the specialized literature, the general problems of biomechanical analysis of contemporary technique and the knowledge of factors decisive for the technical training and contents of the optimization of gymnastics training are insufficiently treated and known. Current concerns in scientific research on the biomechanical issues in gymnastics and the characteristics of rotation routines were expressed by Hochmuth & Marthold, 1987; Bruggmann, 1994; Witten, Brown & Espinoza, 1996; Prassas, Papadopoulos & Krug, 1998 (Creu, Simău & Bărbulescu, 2004).

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. In connection with this fact, V.N. Boloban and E.V. Biriuk (1979) propose the use of the movement postural orientation method for studying the technique of gymnastics sports branches (Potop, Grad, & Boloban, 2013). The concept and methodology of using this method by studying the papers have been perfected during the recent years (Boloban, 1988-2013; Sadovski, Nizhnikovski, Mastalezh, Vishiovski & Begajlo, 2003-2013; Andreeva, 2013, Potop, 2012, 2013, 2014 etc.).

The purpose of the paper is to highlight the biomechanical characteristics of the dismounts off beam at the level of junior gymnasts aged 12-15, performed in the two national competitions.

Hypotheses of the paper: We consider that a comparative biomechanical analysis of the dismounts off the beam will show the influence of the dynamic and kinematic characteristics upon the technical execution in accordance with the performances achieved in competitions.

Material & methods

This study has been conducted throughout the period of two national competitions (C1- National Master Championship, Onești 2012 and C2 – National Individual Championship for Juniors, Onești, 2013). The subjects of the research were 13 female gymnasts, 12 to 15 years old, members of the Junior Olympic Team of Deva, at present moment - of the Olympic Team of Izvorani. The following methods have been used in this research: method of bibliographic study, method of pedagogical observation, method of video biomechanical analysis, method of movement postural orientation, method of pedagogical experiment, statistical method (KyPlot) and method of graphical representation. (Boloban, V., 1990, Sadovski et. al, 2009).

The biomechanical study focused on the analysis of the characteristics of key elements of sports technique used for the dismount using methods from Postural Landmarks of Movements as Main (Key) Elements of Sport Acrobatics Technique (as per Boloban, V., 1990, Sadovski et. al, 2009, adapted for beam in women's artistic gymnastics): PM – preparatory movement (*round-off, round-off with backward flick-flack, walkover 1 foot – walkover*); body launching posture (LP) – *moment of detachment at the end of the beam*, multiplication of body position (MP) – somersault rotation and concluding position (CP) of the body – landing.

The study analyzed 7 dismounts (C1) and 10 dismounts (C2), executed from round-off – layout back somersault with 360°, 540°, 720° and 900° twist; from round off – back walkover – back layout somersault with 720° and 900°; from round off – double back tucked somersault and from back walkover 1 foot – back walkover – back layout somersault with 720° twist and double back pike somersault.

The biomechanical analysis was performed by means of a specialized program called Physics ToolKit Version 6.0, focusing on the key elements of sports technique, using 3 by step calibration / video scene, the type of translation with rotation around GCG; the measuring scale of the distance between two points was the height of the beam, namely 1.20m, and the beam end has been selected as new origin.

Results

The results of the study are presented under graphic and tabular form, highlighting the differences of the kinematic and dynamic characteristics of the dismounts off beam of junior gymnasts 12 to 15 years old, performed in two national competitions 2012 and 2013.

Table no. 1. Anthropometric and biomechanical indicators of junior gymnasts aged 12 -15

Full name	Dismount		Weight, (kg)		Height in handstand, (m)		I.R., (kgm ²)	
	C1	C2	C1	C2	C1	C2	C1	C2
B.A.	FF720°	FF720	34.4	34.6	1.88	1.90	121.6	124.9
C.D.	-	RS900	-	33.2	-	1.82	-	109.9
P.A.	-	RS720	-	29.6	-	1.80	-	90.95
S.A.	-	RDG	-	32.4	-	1.84	-	109.7
V.C.	RFS720	-	35.1	-	1.91	-	128.1	-
I.A.	FFDE	FFDE	31.9	32.1	1.77	1.78	99.9	101.7
T.P.	RS720	RS720	36.9	38.2	1.95	1.96	140.3	146.7
M.A.	-	FF1080	-	33.3	-	1.85	-	113.97
T.D.	-	RDG	-	31.3	-	1.78	-	99.17
N.I.	RS360	RS360	31.9	31.5	1.85	1.86	109.2	108.97
Z.S.	RS900	-	31.7	-	1.77	-	99.31	-
O.A-M	-	RDG	-	40.6	-	1.92	-	149.67
S.S.	RF900	-	38.1	-	1.90	-	137.5	-
Mean			34.28	33.68	1.86	1.85	119.4	115.56
SED			0.98	1.06	0.03	0.02	6.42	6.14
SD			2.58	3.34	0.07	0.06	16.9	19.4
Cv%			7.54	9.93	3.73	3.26	14.23	16.82

Note: C1 – competition no. 1, 2012; C2 – competition no. 2, 2013; RS360° - 900° – round-off backward layout somersault with 360, 540°, 720° and 900° turn; RFS720° - 900° – round-off flick backward layout somersault with 720° and 900° turn; RDG – round off – double back tucked somersault; FF720° – back walkover 1 foot – back walkover – back layout somersault with 720° turn; FFDE – back walkover 1 foot – back walkover – double back pike somersault; IR – inertia rotation; SEM – standard errors deviation; SD – standard deviation.

Table no. 2. Biomechanical parameters (continuation of table 1)

Full names	RM / GCG		Toes		Knee joint		Shoulder joint		Arms joint	
	C1	C2								
B.A.	0.99	0.92	-	-	-	-	0.55	0.51	0.65	0.62
C.D.	-	0.85	-	-	-	-	-	0.48	-	0.54
P.A.	-	0.76	-	-	-	-	-	0.43	-	0.59
S.A.	-	0.68	-	-	0.37	-	-	0.46	-	0.45
V.C.	0.94	-	-	-	-	0.48	-	-	0.52	-
I.A.	0.89	0.78	-	-	-	0.47	0.41	0.59	0.59	0.48
T.P.	0.91	0.82	-	-	-	0.51	0.35	0.64	0.64	0.46
M.A.	-	0.71	-	-	-	-	0.35	-	-	0.39
T.D.	-	0.58	-	-	0.35	-	0.45	-	-	0.40
N.I.	0.82	0.78	-	-	-	0.45	0.47	0.52	0.52	0.54
Z.S.	0.81	-	-	-	-	0.43	-	0.50	-	-
O.A-M	-	0.66	-	-	0.35	-	0.42	-	-	0.34
S.S.	0.92	-	-	-	-	0.54	-	0.63	-	-
Mean	0.89	0.75	-	-	0.36	0.49	0.43	0.58	0.58	0.48
SED	0.02	0.03	-	-	0.01	0.02	0.02	0.02	0.02	0.02
SD	0.06	0.09	-	-	0.01	0.04	0.05	0.06	0.06	0.09
Cv%	7.16	13.19	-	-	3.24	9.20	12.17	11.08	11.08	18.89

Note: RM – radius movement; GCG – general centre of gravitation.

Tables no. 1 and no. 2 show the anthropometric and biomechanical indicators necessary for the biomechanical analysis of the dismount off beam in the case of junior gymnasts 12 – 15 years old, performed in the two competitions. There are also presented the type of dismount, the results of the statistical calculations of the biomechanical indicators in terms of inertia of body rotation, the radius of segments movement GCG (Hip), Toes, Knee joint, shoulder joint and arms.

Table no. 3. Comparative angular characteristics of body segments of the key elements of sports technique in the dismounts off beam (n = 3)

Full names	LP (degrees)		MP-f.m.h. (degrees)		CP (degrees)	
	C1	C2	C1	C2	C1	C2
B.A.	218	198	155	161	111	147
T.P.	216	203	161	164	119	157
I.A.	212	195	68	51	70	88

Note: LP - body launching posture – *moment of detachment at the end of the beam*, MP - multiplication of body position – somersault rotation; CP - concluding position of the body – landing.

Table no. 3 shows the angular characteristics of body segments in the moment positions of the key elements phases of sports technique used in the dismounts off beam executed by 3 gymnasts (B.A., T.P. and I.A.) during the two national competitions.

Table no. 4. Spatial and temporal characteristics of body segments during the dismounts off beam from round-off and back walkover (T.P. and I.A.)

Key elements	Full names	Testing	Times (sec)	GCG		Toes		Shoulders joint		Arms joint	
				X(m)	Y(m)	X(m)	Y(m)	X(m)	Y(m)	X(m)	Y(m)
LP	T.P.	C1	0.033	0.23	1.04	0.17	0.11	-0.15	1.54	-0.41	1.88
		C2*	0.033	-0.3	1.08	-0.26	0.05	-0.12	1.34	0.03	1.78
	I.A.	C1	0.033	0.45	1.05	0.41	0.09	0.32	1.63	0.59	2.14
		C2*	0.033	-0.22	0.93	-0.11	0.02	-0.09	1.35	-0.30	1.86
MP-ÎMZ	T.P.	C1	0.133	-0.63	1.41	0.15	1.96	-1.18	1.16	-1.03	1.12
		C2*	0.1	0.05	1.34	-0.67	1.34	0.36	1.23	0.10	1.57
	I.A.	C1	0.167	-0.54	1.86	-1.39	1.45	-0.73	1.22	-0.94	1.69
		C2*	0.167	0.52	1.52	1.23	1.19	0.52	1.07	0.77	1.47
CP	T.P.	C1	0.367	-2.35	-0.29	-2.34	-1.12	-2.01	-0.17	-1.59	-0.63
		C2*	0.367	0.94	-0.11	0.9	-0.96	0.72	0.03	0.45	-0.14
	I.A.	C1	0.4	-2.22	-0.36	-2.25	-1.22	-1.99	-0.32	-1.88	-0.15
		C2*	0.4	2.05	-0.36	1.83	-1.09	1.69	-0.26	1.94	-0.49

Note: C2* – the dismount direction is opposite compared to C1.

In table no. 4 are listed the spatial-temporal characteristics of body segments during the dismounts off beam from round-off and back walkover (T.P. and I.A.), performed in the two national competitions, as for the horizontal (Xm) and vertical (Ym) travel of GCG, Toes, Shoulders joint and arms joint.

Fig. 1. Results of angular velocities of body segments in the dismounts off beam, gymnasts T.P. and I.A.

Fig. 2. Results of GCG force in dismounts off beam, gymnasts T.P. and I.A.

In figures no. 1 and 2 are listed the angular velocity results and the resultant of comparative force of the key elements in the dismounts off beam, performed by the gymnasts T.P. and I.A. during the two national competitions held in 2012 and 2013.

Table no. 5. Performances achieved in competition (n = 13)

	Ctg.	All-around finals						App. finals			
Full name	Final	D		E		FS		Score		Rank	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	I	F
B.A.	Jun.II	5.700		9.125	8.150	14.825	14.250	14.600	15.100	2	1
C.D	Jun.II	4.800	5.700	8.700	8.100	13.500	13.800	-	14.000	-	4
P.A.	Jun.II	4.800	5.800	8.400	8.000	13.200	13.800	-	13.800	-	6
S.A.	Jun.II	-	5.900	-	9.250	-	15.150	-	15.050	-	3
V.C.	Jun.II	5.300	-	8.275	-	13.575	-	12.750	-	8	-
I.A.	Jun.II	5.800	6.600	8.050	9.350	13.850	15.950	15.050	15.100	1	1
T.P.	Jun.I	5.500	5.500	8.700	9.100	14.200	14.600	13.350	13.750	6	3
M.A.	Jun.I	-	6.400	-	9.200	-	15.600	-	14.800	-	1
T.D.	Jun.I	5.500	5.500	7.575	6.700	13.075	12.200	-	13.300	-	5
N.I.	Jun.I	5.000	5.000	6.750	8.450	11.750	13.450	-	12.850	-	6
Z.S.	Jun.I	5.700	-	8.650	-	14.350	-	13.885	-	5	-
O.A-M	HC	5.500	5.500	7.625	9.000	13.125	14.500	-	12.000	-	-
S.□.	Jun.I	5.600	-	8.525	-	14.125	-	14.535	-	3	-
	Mean	5.38	5.77	8.22	8.53	13.59	14.33	14.03	13.97		
	SED	0.10	0.16	0.20	0.26	0.25	0.35	0.35	0.33		
	SD	0.36	0.49	0.67	0.83	0.83	1.10	0.86	1.06		

Note: HC – off competition, C1 – National Master and Club Representative Teams, One□ti 2012; C2 –National Individual Championship for Juniors, One□ti 2013

Table no. 5 highlights the performances achieved in the competition on beam by the junior gymnasts aged 12 to 15 throughout the two national competitions held in 2012 and 2013, in terms of difficulty, execution and final score in the individual competition and apparatus final.

Discussion

The study was meant to highlight the biomechanical characteristics of the dismounts off beam of junior gymnasts aged 12 to 15, corresponding to the training level 4 and Junior I (Program of classification, 2013). A number of 13 gymnasts participated in this study, out of which 4 attended both competitions carried in One□ti – in 2012 the National Master Championship and in 2013 the National Individual Championship for Juniors.

The biomechanical study of the dismounts off beam has been made by means of the movement postural orientation method (Boloban, 2013), using «Kinovea» and Physics Toolkit programs of biomechanical video analysis, video format AVI with 30 frames / sec. and image calibration at 3 frames in 15 steps.

Regarding the anthropometric indicators needed to make a biomechanical analysis of the dismount off beam in the case of junior gymnasts 12 to 15 years old, we notice an average weight of 34.28 kg in Competition 1 (C1) and 33.68 kg in Competition 2 (C2); the height in handstand has a mean of 1.86 m at C1 and 1.85 m at C2 (table no. 1).

In terms of biomechanical indicators necessary for the analysis, the inertia of body rotation has a mean of 119.4 kgm^2 during C1 and a decrease by 3.84 kgm^2 during C2, having a mean of 115.56 kgm^2 ; the radius of body segments movement in the analyzed dismounts has a mean of 0.89 m for the Toes during C1 and 0.75 m during C2; for Knee joint there is a mean of 0.36 m during C2; at shoulders joint level there is a mean of 0.49m during C1 and a decrease by 0.05m during C2 (a mean of 0.43m); at arms joint the mean is 0.58m during C1 and 0.48 m during C2 (table no. 2). These differences of segments movement radius highlights the improvement of execution technique of the round-off or back walkover preparatory movement, of the body position during flight phase in the multiplication of posture (tucked, pike or layout with $360^\circ - 900^\circ$ turn), of the landing accuracy and sureness in the final stage of the dismount.

In order to point out the biomechanical characteristics of the dismount off beam, we gave the example of two gymnasts that performed the dismount as follows: the gymnast T.P. from round off – layout somersault with 720° turn (RS720°) in both competitions and the gymnast I.A. from back walkover 1 foot – back walk over – double back pike somersault (FFDE). The analysis of the angular characteristics of the sports technique key elements, measured by means of Kinovea program, is shown in table no. 3 where we notice the correction of the starting position before flipping off (LP); the maximum height of GCG in the flight phase during the multiplication of body posture at tucked position of 1.41 in C1 and 1.34 m in C2 – dismount RS720 and 1.86m during C1 and 1.52m during C2 at the dismount from FFDE and accuracy of landing in the final stage of the dismount (length – 2.34 – 0.9m).

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 19.47 – 30.29 rad/sec; in MP phase, in f.m.h. (*flight maximum height*) an angular velocity of 21.42 – 24.06 rad/sec at toes level RS720 and shoulders and toes in FFDE dismount and in CP – landing – a velocity of 10.9 – 26.23 rad/sec at arms level in both dismounts (fig.2).

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 2810 – 5580 N, in MP phase f.m.h. – 11900 - 3700 N and in CP phase– landing of 185.7 – 6260 N (fig.3). The analysis of sports performances achieved in competitions highlight an increase of exercise difficulty, having a mean of 5.38 points during C1 and 5.77 points during C2, an improvement of both execution (8.22 points during C1 and 8.53 points during C2) and final score in the individual all-around competition (13.59 points during C1 and 14.33 points during C2); we also notice a small decrease of the score in the apparatus finals from 14.03 points during C1 to 13.97 points during C2 (table no. 5).

Conclusions

The comparative analysis between dismounts execution and the requirements of the technical regulations included in the international Code of Points for beam will determine new methodological guidelines meant to improve and correct them.

The biomechanical study of the dismounts off beam made by means of the method of movement postural orientation highlights the key elements of sports technique in terms of the preparatory movement (*round-off, round-off with backward flick-flack, back walkover 1 foot – back walkover*); body launching posture (LP) – *moment of flipping off at beam extremity*, multiplication of body position (MP) – somersault rotation and concluding position (CP) of the body – landing.

The performance of the comparative biomechanical analysis of the dismounts off the beam highlight the influence of the kinematic and dynamic characteristics upon the technical execution in accordance with the performances achieved in competitions.

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