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Original Article

Biomechanical characteristics of back double salto dismount off the uneven bars

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Abstract:
This paper aims at highlighting the biomechanical characteristics of the back double salto dismount off the uneven bars in women's artistic gymnastics. This scientific approach has led to the organization of a study conducted throughout two national competitions 2012 and 2013, with a group of 6 junior gymnast's aged 12 to 15, members of the junior Olympic team of Izvorani. The biomechanical analysis has been performed by means of Physics Toolkit program and of the movement postural orientation method, highlighting the key elements of the sports technique used in back double salto dismount off the uneven bars. The results of the study showed the anthropometric and biomechanical indicators necessary for the biomechanical analysis of the back double salto dismount off the uneven bars. The comparative biomechanical analysis of the back double salto dismount off the uneven bars 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, uneven bars, 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).

In conformity with the requirements and the specific character of women's artistic gymnastics apparatus, the elements on uneven bars can be divided into several structural groups, defined not only according to their execution way, but also according to their purpose, namely: handstands, hip circles (small and big), free passing over bars, saltos and regrasping, simple switches on longitudinal axis or made during different basic movements, transitions from one bar to another, mounts and dismounts (Bibire & Dobrescu, 2008; Grosu, 2004; Vieru, 1997); the dismounts off the uneven bars correspond to the 6^{th} group of the International Code of Points, having different values and groups of difficult: tucked B – 0.2 points – double back tuck salto, group C - 0.3 points – double back pike salto and group D -0.4 points – double back tuck salto with 360° twist in the first salto.

"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

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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). The last element closing the routine gives the final impression and is ended by a standstill landing. This element is called dismount. The development of gymnastics tried to impose a great variety of dismounts created by the fertile imagination of the gymnastics world. Due to the improvement of the working apparatus that changed the style a lot, uneven bars became a very dynamic event, formed of elements of large amplitude that were executed cursively, which required that the dismounts comply with this style too. Therefore, the more frequent and promising dismounts of all the interesting and inspired ones seem to be the dismounts belonging to salto family. They prevailed because they are closely related to floor acrobatics, which facilitates and simplifies the learning to a great extent. The positive transfer acts often in a beneficial way in both directions, saving the most precious capital of the performance: time (Bibire, Dobrescu, 2008). 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, Papadopulous & Krug, 1998 (Creţu, Simăn & 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; Potop, 2012, 2013; Andreeva, 2013 etc.).

The purpose of the paper is to highlight the biomechanical characteristics of the back double salto dismount off the uneven bars in women's artistic gymnastics.

Hypotheses of the paper: We consider that a comparative biomechanical analysis of the double back salto off the uneven bars will highlight the influence of the kinematic and dynamic characteristics on the technical execution in accordance with the performances achieved in competitions.

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 Physical Education and Sport of Ukraine for 2011 -2015. National registration number: 0111U001726. Index UDK: 796.012.2.

Material & methods

This study was conducted over the period of two national championships (C1- National Masters Championships, Oneşti 2012 and C2 – Individual National Championships of Juniors, Oneşti, 2013). The subjects of the research were 6 female gymnasts, 12 to 15 years old, members of the Junior Olympic Team of Deva, at the present moment - 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 using Physics Toolkit program, method of movement postural orientation, method of pedagogical experiment, statistical method (KyPlot) and method of graphical representation. The biomechanical study focused on the analysis of the characteristics of key elements of sports technique used for the dismount with backward double tucked, tucked with turn 360 ° and pike salto (Boloban, V., 1990, Sadovski et. al, 2009): preparatory movement - spring under bar (PM) – Sub-phase 1; body launching posture Sub-phase 2 (LP) – moment of release of the bar, multiplication of body position (MP) – somersault rotation and concluding position (CP) of the body – landing.

Results

Table 1. Anthropometric and biomechanical indicators of junior gymnasts 12 -15 years old

Full name	Dismount		Weight, *(kg)*		Height in handstand, *(m)*		R.I., *(kgm^2)*	
	C1	C2	C1	C2	C1	C2	C1	C2
B.A.	TDS	PDS	34.4	34.6	1.88	1.90	121.58	124.91
C.A.	TDS360°		33.5	33.2	1.80	1.81	108.54	108.77
O.A-M.	PDS		39.0	40.6	1.92	1.92	143.77	149.67
T.D.	PDS		29.7	31.3	1.78	1.78	94.10	99.17
T.P.	PDS		36.9	38.2	1.95	1.95	136.71	145.26
I.A.	PDS	TDS360°	31.9	32.1	1.77	1.77	99.94	100.57
	Mean		**34.23**	**35.00**	**1.85**	**1.86**	**117.44**	**121.39**
	SED		1.37	1.49	0.03	0.03	8.19	9.07
	SD		3.36	3.66	0.08	0.08	20.05	22.21
	Cv%		9.81	10.47	4.16	4.19	17.08	18.30

Note:C1 – competition 1, 2012, C2 – competition 2, 2013, TDS - tucked double salto dismount, PDS- pike double salto dismount, TDS360° - tucked double salto 360° turn (twist first salto) - R.I.- rotational inertia; R.M.-

radius of movement; GCG –general centre of gravity (hip); toes; knee joint; shoulder joint; wrist joint; SEM – standard error means; SD – standard deviations.

Table 2. Biomechanical parameters (continuation of table 1)

	Radius of movement, (m)									
	GCG		Toes		Knee joint		shoulder joint		Arms	
	C1	C 2	C1	C2	C1	C2	C 1	C2	C1	C2
B.A.	1.33	1.12	1.77	1.58	1.54	1.34	1.12	0.93	0.93	0.67
C.A.	1.34	1.14	1.75	1.55	1.57	1.35	1.19	0.91	1.01	0.76
O.A-M.	1.27	1.13	1.69	1.51	1.45	1.31	1.04	0.90	0.85	0.71
T.D.	1.28	1.05	1.67	1.48	1.47	1.26	1.06	0.82	0.84	0.64
T.P.	1.21	1.28	1.67	1.68	1.42	1.46	0.92	1.06	0.68	0.88
I.A.	1.31	1.21	1.74	1.62	1.49	1.41	1.08	1.02	0.87	0.88
Mean	**1.29**	**1.16**	**1.72**	**1.57**	**1.49**	**1.36**	**1.07**	**0.94**	**0.86**	**0.76**
SED	0.02	0.03	0.02	0.03	0.02	0.03	0.04	0.03	0.04	0.04
SD	0.05	0.08	0.04	0.07	0.06	0.07	0.09	0.08	0.11	0.10
Cv%	3.70	6.89	2.55	2.55	4.66	5.25	8.42	9.25	12.72	13.70

In tables 1 and 2 are listed the anthropometric and biomechanical indicators needed to make a biomechanical analysis of back double salto off the uneven bars performed by the junior gymnasts 12 to 15 years old in the two competitions mentioned above. There are also shown, in terms of dismount type, the results of the statistic calculations of biomechanical indicators as for the inertia of body rotation, the radius of the movement of the segments GCG (Hip), Toes, Knee joint, shoulder joint and arms.

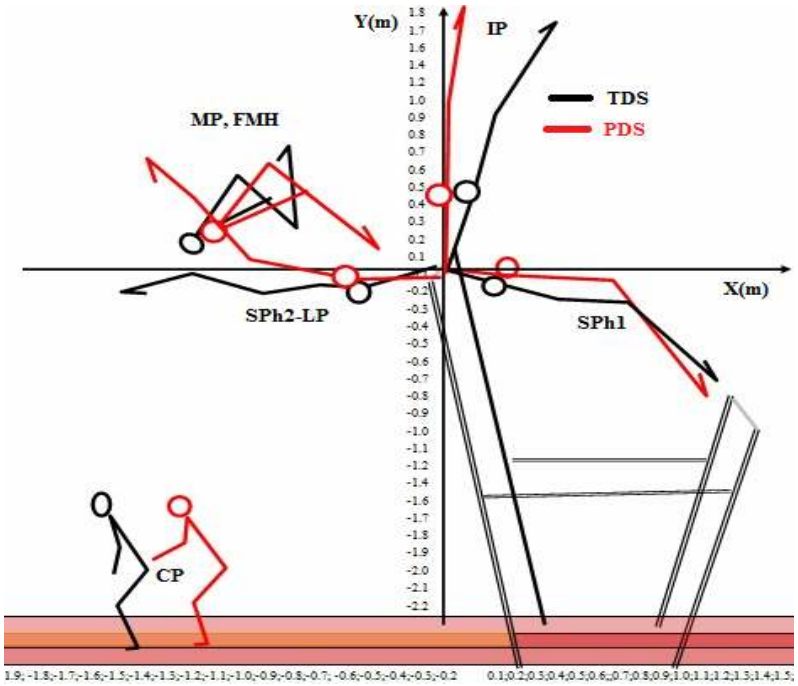
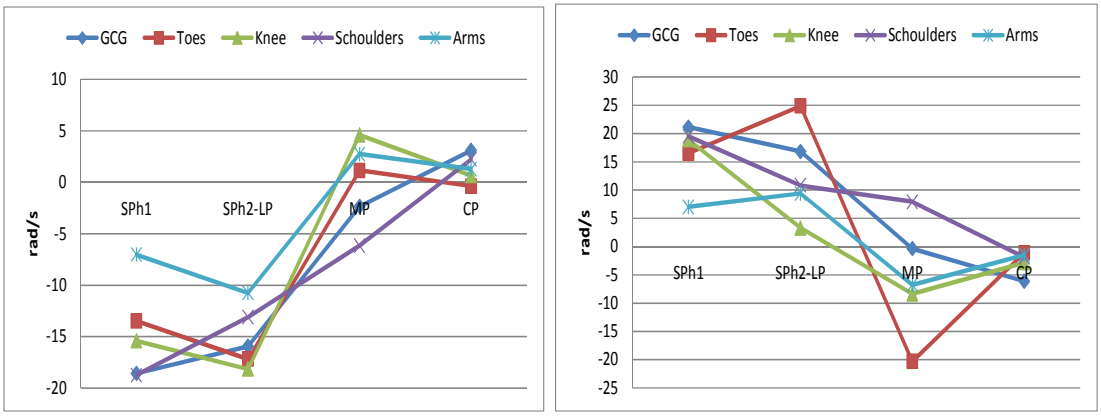


Fig.1. Spatial characteristics of the key elements of back double salto dismount(tucked and pike) off uneven bars, gymnast (B.A.)

Note: IP- initial position, SPh1 – sub-phase 1 – passing over low bar; SPh2 – L.P. – sub-phase 2 – body launching posture (release of bar); BP – basic phase, MP – FMH – multiplication of body posture – flight maximum height; FP – final phase, CP – concluding body posture (landing)- CP.

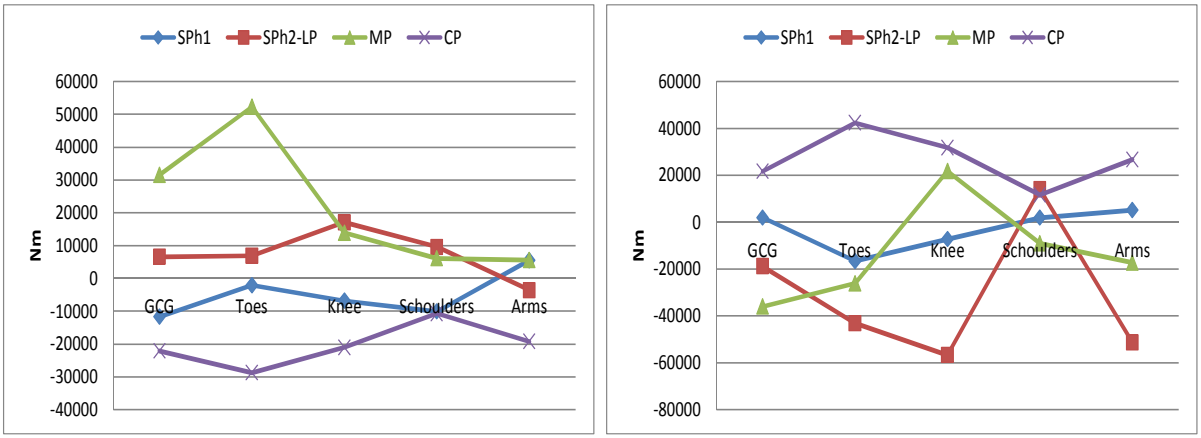
Figure 1 shows the comparative spatial characteristics of the key elements of the back tuck and pike double salto dismount off uneven bars, performed by the gymnast B.A. during the two national competitions held in 2012 and 2013, highlighting the preparatory movement of launching from handstand, launching posture (LP) – release of the bar, multiplication of body posture in tuck and pike position at the maximum height of GCG and the concluding posture (CP) –landing.



a) Competition 1 (TDS) b) Competition 2 (PDS)

Fig.2. Kinematic characteristics of the angular velocity of body segments in back double salto dismount off uneven bars (B.A.)

In figure no. 2 are shown the kinematic characteristics of the angular velocity of body segments in the tuck and pike double salto dismount off uneven bars, performed by the gymnast B.A. in the two national competitions.



a) Competition 1 (TDS) b) Competition 2 (PDS)

Fig. 3. Dynamic characteristics of force momentum of body segments in the back double salto dismount off the uneven bars (B.A.)

Figure 3 presents the dynamic characteristics of force momentum of body segments in the back tuck and pike double salto dismount off the uneven bars executed by the gymnast B.A. in the two national competitions.

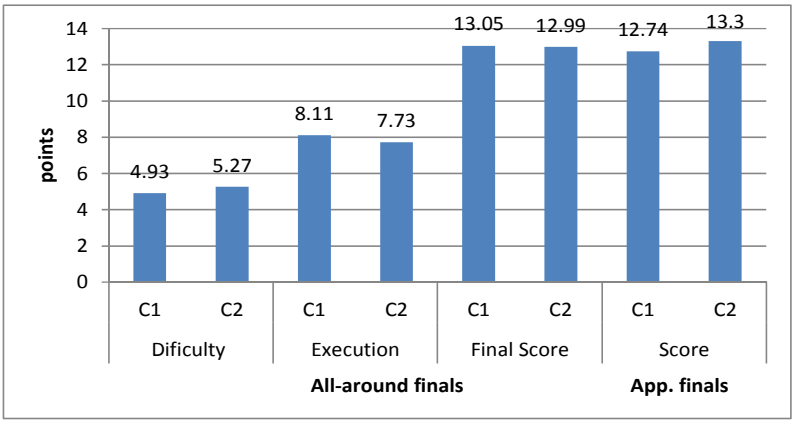


Fig.4. Results of the performances achieved in competitions

Table 3. Performances achieved in competition

Full name	Category	All-around finals						App. finals			
		Dificulty		Execution		Final Score		Score		Rank	
		C1	C2	C1	C2	C1	C2	C1	C2	C1	C2
B.A.	Jun.II	4.500	5.700	8.500	8.300	13.000	14.000	12.725	13.800	4	2
C.A.	Jun.II	4.800	5.500	6.775	7.600	11.575	13.100				
O.A-M	Jun.I	5.100	5.000	8.550	8.600	13.650	13.600	12.600	13.000	5	HC
T.D.	Jun.I	4.800	4.900	7.425	7.000	12.225	11.900	12.125	11.800	6	4
T.P.	Jun.I	5.100	5.000	8.525	8.000	13.625	13.000	13.100	13.200	3	1
I.A.	Jun.II	5.300	5.500	8.900	6.850	14.200	12.350	13.125	14.700	2	1
	Mean	**4.93**	**5.27**	**8.11**	**7.73**	**13.05**	**12.99**	**12.74**	**13.30**		
	SED	0.12	0.14	0.34	0.29	0.40	0.32	0.18	0.48		
	SD	0.29	0.34	0.82	0.82	0.98	0.77	0.41	1.07		
	Cv%	5.83	6.43	10.16	9.11	7.56	5.96	3.23	8.03		

Note: HC – outside competition, C1 – National Masters and Club Representative Teams Championships, Oneşti 2012; C2 – National Individual Championships for Juniors, Oneşti 2013

Table 3 and figure 4 present the performances achieved by the junior gymnasts aged 12 to 15 in the two national competitions carried out in 2012 and 2013 in terms of difficulty, execution and final score in the all-around finals and apparatus finals.

Discussions

The study was conducted with the purpose to highlight the biomechanical characteristics of the back double salto dismounts off the uneven bars in the case of junior gymnasts 12 to 15 years old. A number of 6 gymnasts participated in this study, who competed in both events held in Oneşti – in 2012 in the National Masters Championships and in 2013 in the National Individual Championships for Juniors.

The biomechanical study of back double salto dismounts off uneven bars has been made by means of the movement postural orientation method (Boloban, 1990), using the biomechanical video analysis program Physics Toolkit, with spatial reference points of origin – the bar and gymnast's body posture in handstand; AVI video format with 30 frames / sec and image calibration at 4 frames in 21 steps.

Regarding the anthropometric indicators necessary for the biomechanical analysis of the back double salto dismount off uneven bars at the level of junior gymnasts aged 12 to 15, we notice an average weight of 34.23 kg in the Competition no. 1 (C1) and 35.00 kg in the Competition no. 2 (C2); the height in handstand has a mean of 1.85 m at C1 and 1.86 m at C2 (table 1).

In terms of biomechanical indicators necessary for the analysis, the inertia of body rotation has a mean of 117.44 kgm^2 at C1 and an increase by 3.95 kgm^2 at C2, having a mean of 121.39 kgm^2; the radius of body segments movement in the analyzed dismount shows a mean of the GCG of 1.29 m at C1 and 1.16 m at C2; at the toes there was a mean of 1.71 m at C1 and a decrease by 0.15 m at C2 (1.57 m); the knees have a mean of 1.07 m at C1 and 0.94 m at C2; the arms – 0.86 m at C1 and 0.76 m at C2 (table 2). These differences of segments movement radius emphasize the improvement of execution technique of the preparatory movement for launching from handstand, of the body posture in the flight phase during the multiplication of posture (tucked, pike or 360° twist in the first salto), the accuracy and exactness of the landing in the final phase of the dismount.

In order to highlight the biomechanical characteristics of the back double salto dismount off uneven bars we gave the example of the gymnast B.A. who performed a dismount with tuck double salto in C1 and pike double salto in C2. The spatial characteristics of the key elements of sports technique are shown in figure 1 where it can be noticed the correction of the launching posture in the preparatory phase SPh1 – passage over lower bar, release of the bar in SPh2 (LP) higher than the horizontal of the bar (over the bar); increase of the maximum height of GCG in the flight phase during the multiplication of the body posture in tuck salto of 0.53 m in C1 and 0.59 m in pike salto in C2 and exactness of the landing in the final phase of the dismount.

Regarding the kinematic characteristics of the angular velocity of body segments during tuck double salto dismount in C1 and pike double salto dismount in C2, we notice an increase of the angular velocity more obvious at toes level, having values between -13.47 – (-17.18) rad/s in C1 and 16.52 – 24.89 rad/s in C2 while at MP – 20.29 rad/s (fig.2).

In terms of dynamic characteristics of force momentum of body segments, we notice the effect of rotation of the force during the dismount with tuck double salto in C1, having higher values at toes level -52300 Nm – (maximum height of GCG); in the case of pike double salto, in C2 – 43100 Nm at bar release (SPh2 –LP) and at landing 25700 Nm (fig.3).

The analysis of sports performances achieved in competitions highlights an increase of the exercise difficulty, with a mean of 4.93 points in C1 and 5.27 points in C2, a decrease of the execution of 8.11 points in C1 and 7.73 points in C2 and of the final score in the all-around finals of 13.05 points in C1 and 12.99 points in C2 and an improvement of the score in the apparatus finals from 12.74 points in C1 to 13.30 points in C2 (table 4).

Conclusions

The comparative analysis between dismounts execution and the requirements of the technical regulations included in the international Code of Points for uneven bars will determine new methodological guidelines meant to improve and correct them.
The biomechanical study of the back double salto dismounts off the uneven bars performed by means of the postural orientation method highlights the key elements of sports technique as for the preparatory movement (PM) - spring under bar (Sub-phase 1); body launching posture (LP) Sub-phase 2 – moment of release of the bar, multiplication of body position (MP) – somersault rotation and concluding position (CP) of the body – landing.
The comparative biomechanical analysis of the back double salto dismount off the uneven bars highlights the influence of the kinematic and dynamic characteristics on the technical execution in accordance with the performances achieved in competitions.

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