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Original article

COMPARATIVE STUDY OF THE BIOMECHANICAL CHARACTERISTICS OF LANDINGS PERFORMED AT VAULT

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Abstract

Aim: Landing in modern gymnastics is one of the most important factors which determine the final rank of gymnasts at competitions. The main purpose of this paper is to highlight and compare the characteristics of landings performed at vault, at level 4 gymnasts, age 12-13 years old.

Methods: The study was conducted at the Juniors Individual National Championships, Onești 2013 and Deva 2014. The study`s subjects were three level 4 gymnasts, vault finalists, in the two championships.

The study analysed 12 landings. Each one of the gymnasts performed two vaults at each championship. These were biomechanically analysed and then compared. The comparative study was conducted both between all the gymnasts vaults, and between each one`s vaults, individually.

The research methods used in the study were: bibliographical study, observation method, biomechanical video analysis method and statistical and graphic representation method.

Results: By analysing all the vaults, we observe that the flyght`s lenght was shorter in 2014 (PF1=1,50m), compared with 2014 (1,91m), althrough the flyght`s heigh wasn`t higher (0,43m in 2013 and 0,28m in 2014). The horisontal displacement of body segments shows that also the two phases of the landing was higher in 2014 (PF1=1,50m and PF2=1,93m), compared with 2013 (PF1=1,91m and PF2=2,23m). The results of the sports performances obtained in competition and the landings penalties, highlights an final average mark of 13,43 points in the apparatus finals in 2013, a decrease of final average of 0,40 points in 2014 (13,03 points). The same difference of 0,40 points was also recorded between the landings penalties at both competitions (1,60 points in 2013 and 2,00 points in 2014).

Conclusions: The biomechanical study of the landings performed at vault highlights that the gymnasts don`t master the landings, doing execution mistakes and losing important points. Therefore, we consider that there is necessary to perform a training program of landings.

Key Words: biomechanics, landings, vault, artistic gymnastics, sport performance.

Introduction

Artistic Gymnastics posses in present a new level of development, on the exercise content and assesment. (Potop, 2008). It is characterised by a high, rich and varied content of elements and technical processes.

Biomechanical research in artistic gymnastics, performed with specialized programs can be effective in identifying and correcting technical errors. These researches are helping both the coach, to guide the activity on improving the studied parameters and implementation of effective programs for correcting mistakes, and the gymnast to identify and acknowledge the mistakes she made during the execution.

Technical training is very important in artistic gymnastics, because only a correct technique provides insights acquired progress (Vieru, 1997), but only if it is in a close interdependence with the other components. (Grigore, 2001)

The Vault apparatus is one of the most dynamic and spectacular tests found in the Artistic Gymnastics specific competition program. This test requires special qualities from the athletes: power, speed, coordination, spatial and temporal orientation. (Manos, 2008)

Landing in modern gymnastics is one of the most important factors which determine the final rank of gymnasts at competitions. (Marinsek and Cuk, 2008).

Landing success depends on the physical fitness (preparation) and motor control of the gymnast. Physical preparation refers to the gymnast's ability to cope with the load to which they are exposed during the landing. Motor control refers to the control the gymnast has over the skill they perform. Both of these factors enable successful and safe landings.

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(Marinsek, 2010).

According to a Classification Program, a level 4 gymnast must perform two vaults with salto, freely chosen, identical or different from the Code of Points, for the National Junior Championship - teams and individual and two vaults with salto, freely chosen, different as number or group from the Code of Points, for the National Junior Championship - final. (Classification Program, 2010-2013, 2014-2017).

Landing penalties are applied in accordance with the FIG Code of Points; 0.1 points - small mistake; 0.3 - Average mistake; 0.5 points - big mistake; 0.8 points - the maximum deduction if there is no fall and 1 point – fall . The penalties apply to the following faults: landing legs apart, landing too close to the apparatus, extra arms and torso movements, additional steps, body posture fault, very low landing, fall. (Code of Points, 2013)

The main purpose of this paper is to highlight and compare the characteristics of landings performed at vault, at level 4 gymnasts, age 12-13 years old.

We consider that by using the biomechanical analysis method using computerized video method upon the vault landings, we will highlight the evolution of gymnasts registered in a year, according to the performances in the competition.

Methods

The study was conducted at the Juniors Individual National Championships, Onești 2013 and Deva 2014. The study`s subjects were three level 4 gymnasts, vault finalists, in the two championships.

The study analysed 12 landings for the following vaults: Yurchenko – tucked salto backward off (2 vaults), Yurchenko – piked salto backward off (one vault), Yurchenko - stretched salto backward off (5 vaults), Yurchenko – stretched salto backward with 1/1 turn off (2 vaults), Tsukahara piked (2 vaults). Each one of the gymnasts performed two vaults at each championship. These were biomechanically analysed and then compared. The comparative study was conducted both between all the gymnasts vaults, and between each one`s vaults, individually.

The research methods used in the study were: bibliographical study, observation method, biomechanical video analysis method and statistical and graphic representation method.

The biomechanical analysis was performed by means of a specialized software called Physics ToolKit Version 6.0, using the type with translational motion of rotation around the General Center of Gravity (GCG) of the body; the scale for measuring the distance between two points was the height of the vault table and the center of the vault table was chosen as the new origin. Also, to analyse and to calculate the angles of the segments, was used the Kinovea program.

The biomechanical study is focused on the characteristics` analysis of technique's key elements of the landing, using methods from Postural Landmarks of Movements as Main (key) Elements of Sport Acrobatics Technique (Boloban, 1990): start position of the body (SP) – the moment of taking off from the table, multiplication of body position (MP) – the maximum height of flight of General Centre of Gravitaty (GCG) , and final position of the body – the landing time of first contact (FP1) and final position (FP2).

Results

Table 1 shows the anthropometric indices (the height and weight of the athletes) and biomechanical indices (rotational inertia and the radius of rotation between CGGC, shoulders and toes), required to analyse the vaults landings. Each index is presented both for 2013 and for 2014. In addition, the following statistical indicators were calculated: arithmetic mean and standard deviation.

Table 1. Anthropometric and biomechanical indices used to analyze the landings at vault, in 2013-2014

	Name	Height (m)		Weight (kg)		I.R., kgm^2		R.M. / G.C.G., (m) Shoulders				Toes			
								2013		2014		2013		2014	
		2013	2014	2013	2014	2013	2014	I	II	I	II	I	II	I	II
1	C.O.	1.41	1.50	29	33	57.65	74.25	0.42	0.39	0.35	0.41	0.65	0.56	0.71	0.63
2	C.I.	1.37	1.41	31	32	58.18	63.62	0.40	0.41	0.37	0.37	0.72	0.71	0.67	0.68
3	M.A.	1.42	1.46	32.5	34	65.53	72.47	0.51	0.38	0.34	0.34	0.90	0.67	0.70	0.70
	Mean	1,40	1,46	30,83	33	60,45	70,11	0,42		0,36		0,70		0,68	
	SD	0,03	0,05	1,76	1,00	4,40	5,69	0,05		0,03		0,11		0,03	

I.R., rotational inertia; R.M., radius of movement between General Centre of Gravity (GCG), shoulders

and toes; I, first vault; II, second vault; SD, standard deviation.

Table 2 presents gymnast`s jumping codes, executed in the two championships, and the body segments angles, calculated Kinovea program, in the four studied phases.

Table 2. The angular characteristics of body segments

	Name	Vault		SP		MP				FP1		FP2			
				<oriz		<T-T		<T-C		<V-S		<T-T		<T-C	
		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
1	CO	4.30	4.30	88	69	127	127	-	-	82	67	124	104	113	96
		4.10	4.10	86	78	104	120	87	73	47	43	122	144	129	117
2	C.I.	4.30	4.30	68	65	142	133	-	-	53	65	147	122	112	107
		4.32	4.32	64	68	156	158	-	-	56	63	149	131	126	136
3	M.A.	3.20	320	74	90	98	97	-	-	87	73	122	116	113	120
		4.20	4.30	61	73	95	126	-	-	74	69	111	114	118	110
	Mean			73,50	73,83	120,3	126,8	87	73	66,50	63,33	129,2	121,8	118,5	114,3
	SD			11,34	9,11	25,27	19,73			16,67	10,54	15,30	14,06	7,34	13,54

4.30, Yurchenko - stretched salto backward off; 4.10, Yurchenko – tucked salto backward off; 4.32, Yurchenko – stretched salto backward with 1/1 turn off; 3.20, Tsukahara piked; 4.20, Yurchenko – piked salto backward off; SP, start body position ; MP, multiplication body position; FP1, final position – landing (first contact with floor); FP2, final position ; ∟V-S, angle between Vertical and Shoulders; ∟T-T, angle between Torso and Thigh; ∟T-C, angle between Thigh and Calf

Table 3 presents the results of horizontal displacement of segments (x) and vertical (y) in the 4 phases of the landing: start position, the maximum height of the body in flight, the first feet contact with the ground, for landing and fixing the landing, in the two years.

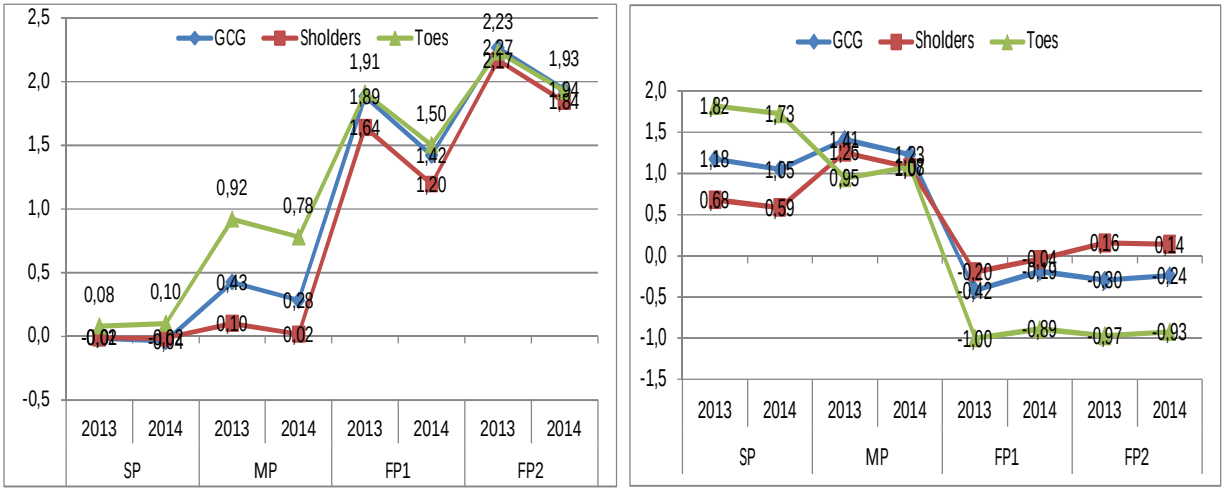
Tabel 3. Body segments` spatial characteristics

Name	Vault		Key	GCG (m)				Shoulders(m)				Toes (m)			
				x		y		x		y		x		y	
	2013	2014		2013	2014	2013	2014	2013	2014	2013	2014	2013	2014	2013	2014
CO	4.30	4.30	SP	-0.01	-0,12	1.13	1,04	0	-0,07	0.64	0,59	0.37	0,27	1.8	1,71
			MP	0.4	0,3	1.27	1,21	0.13	0,05	1.18	1,14	0.82	0,89	0.65	0,77
			FP1	1.66	1,21	-0.46	-0,15	1.46	0,99	-0.19	-0,03	1.68	1,29	-0.97	-0,89
			FP2	1.82	1,46	-0.33	-0,2	1.68	1,29	0.10	0,2	1.73	1,41	-0.92	-0,89
	4.10	4.10	SP	0.03	0	1.18	1,19	0.03	0,03	0.67	0,73	-0.09	0,10	1.62	1,79
			MP	0.43	0,34	1.34	1,38	0.09	0,10	1.18	1,25	0.80	0,75	1.4	1,45
			FP1	1.83	1,43	-0.37	0	1.68	1,17	-0.03	0,21	1.83	1,61	-0.92	-0,83
			FP2	2.46	2,02	-0.29	-0,21	2.35	1,92	0.12	0,29	2.43	1,97	-0.92	-0,96
C.I.	4.30	4.30	SP	-0.1	-0,06	1.06	1,1	-0.04	-0,03	0.58	0,61	0.01	-0,03	1.89	1,89
			MP	0.28	0,19	1.34	1,29	-0.03	-0,05	1.12	1,03	0.89	0,82	1.05	1,27
			FP1	1.79	1,55	-0.55	-0,35	1.59	1,35	-0.29	-0,10	1.81	1,54	-1.05	-0,91
			FP2	2.24	2,18	-0.51	-0,25	2.18	2,09	-0.04	0,14	2.2	2,22	-1.04	-0,93
	4.32	4.32	SP	-0.13	-0,15	1.06	0,97	0.01	0,03	0.62	0,48	-0.41	-0,55	1.64	1,39
			MP	0.59	0,25	1.44	1,22	0.19	0	1.58	0,90	1.03	0,67	0.77	1,67
			FP1	2.03	1,67	-0.46	-0,38	1.79	1,51	-0.21	-0,13	2.06	1,65	-0.99	-0,90
			FP2	2.48	2,41	-0.31	-0,30	2.46	2,32	0.15	0,04	2.49	2,4	-1.01	-0,93
M.A.	3.20	3.20	SP	0.09	0,05	1.51	1,03	-0.08	0	0.89	0,50	0.56	0,42	2.27	1,83
			MP	0.57	0,32	1.74	1,11	0.16	0	1.5	1,08	1.1	0,61	0.8	0,58
			FP1	2.37	1,24	-0.27	-0,24	2.01	1,03	-0.13	-0,12	2.37	1,24	-1.01	-0,93
			FP2	2.72	1,83	-0.03	-0,19	2.58	1,8	0.54	0,13	2.73	1,83	-0.95	-0,93

4.20	4.30	SP	0.03	0,05	1.11	0,96	0	-0,05	0.68	0,6	0.04	0,39	1.71	1,74
		MP	0.28	0,29	1.35	1,17	0.06	0	0.98	1,04	0.87	0,94	1.00	0,76
		FP1	1.63	1,43	-0.42	-0,03	1.32	1,12	-0.33	-0,08	1.71	1,69	-1.08	-0,88
		FP2	1.88	1,72	-0.32	-0,29	1.75	1,64	0.06	0,03	1.82	1,74	-0.99	-0,91

SP, Start position; MP, Multiplication position; FP1, Final position 1; FP2, Final position 2.

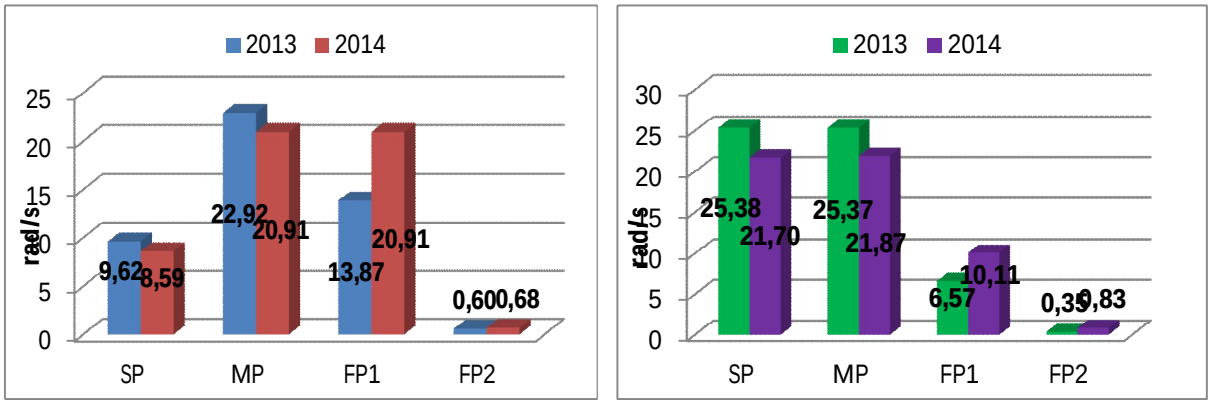
Figure 1 presents the results of the average trajectories of body segments (GCG, toes and shoulders), highlighting the key elements of the vault landings` technique, in the horizontal displacement (Fig. 1a) and vertical (Fig.1b).



a) The horizontal displacement of body segments b) The vertical displacement of body segments

Figure 1. The results of the body segments` trajectories at vault`s landings

Figure 2 presents the results average of the angular velocity of the body segments relationship, shoulders (fig.2a) and toes (fig.2b) rotation around the GCG, in vaults landings execution, of the three gymnasts, at the two competitions.



a) The angular velocity shoulders rotation around GCG relationship

b)The angular velocity toes rotation around GCG relationship

Figure 2. The mean of the angular velocity`s results

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In table 4 are presented the three gymnasts performances obtained in the apparatus finals at vault event, and the obtained penalties for each of the landings, in the two competitions.

Table 4. Performances achieved in competitions and the landings penalties

	Name	Vault	Landing penalties		Apparatus finals 2013		2014	
			2013	2014	Score	Rank	Score	Rank
1	C.O	4.30	0,1	0,1	13,225	4	13,950	1
		4.10	0,5	0,3				
2	C.I	4.30	0,3	0,5	13,850	1	13,450	1
		4.32	0,3	0,5				
3	M.A.	3.20	0,3	0,5	13,225	4	12,675	6
		4.20/4.30	0,1	0,1				
	Mean		0,27	0,33	13,43		13,03	
	SD		0,15	0,20	0,36		0,39	
	Sum		1,60	2,00				

Discussions

For the study have participated three level 4 gymnasts, aged 12-13 years, primarily aiming to highlight and compare the vaults landings` characteristics performed at the National Individual Championships of junior Onesti 2013 and Deva 2014.

According to the Code of Points (Code of Points, 2013), in women's artistic gymnastics, handspring vaults are divided into five groups; the vaults performed by the gymnasts belongs to groups III (Handspring with ¼ - ½ turn (90° - 180°) in 1st flight phase (Tsukahara) – salto backward with or without turn in 2nd flight phase) and IV (Round-off (Yurchenko) with or without 3/4 turn (270°) in 1st flight phase – salto backward with or without turn in 2nd flight phase).

All these handspring vaults have in common the composing phases, namely: running, hurdle onto springboard, first flight, hands support on table (handspring), second flight and the landing. (Corlaci, 2010). The biomechanical study is focused on the characteristics` analysis of technique's key elements of the landing.

To perform the biomechanical study was necessary the introduction of anthropometric and biomechanical indicators, from which was calculated the average rotational inertia of 60,45 kgm^2, in 2013 and 70,11 kgm^2, 2014. The rotation radius of the toes was of 0,70m in 2013 and 0,68m in 2014, and of the shoulders was 0,42m in 2013, respectively 0,36m in 2014. In terms of anthropometric indices, there is observed an increase of the average height in 2014 by 6 centimeters and of the weight by about 2kg. (Table 1)

After analyzing the landing, we have noticed that the gymnasts C.O. and C.I. executed the same jump in the two years, and the gymnast M.A. performed a jump with a higher D-score in 2014.

Looking at the kinematic characteristics of the body segments` trajectories, in the horizontal movement, we observe the following:

- At the first vault of the gymnast C.O., the distance between FP1 and FP2 was higher in 2014, their values being PF1 = 1,68m and PF2 = 1,73m in 2013 and PF1 = 1,29m and PF2 = 1,41m, in 2014. On the second vault, she managed to reduce this distance, from 0,60m, in 2013, to 0,36m, in 2014.

- At the first vault, the gymnast C.I. registered a large difference between the two phases of the landing, as follows: in 2013, PF1 = 1,82 and PF2 = 2,2m, and in 2014, PF1 = 1,54 and PF2 = 2, 22m. On the second vault, the difference between the first feet contact with the ground and fixing the landing increased by 0,32m in 2014.

- At the gymnast M.A., the difference between the two phases of the first vault`s landing increased in 2014 from 0,36m to 0,59m. On the second vault, the values of the first and second moment of landing were: PF1 = 1,71m and PF2 = 1,82m, in 2013 and PF1 = 1,69m and PF2 = 1,74m, in 2014.

In the vertical movement of the body segments it is observed that the overall maximum height of the Genera Center of Gravity of the body, in the multiplication body phase, decreased in 2014. The biggest difference was 0,34m, identified at the gymnast C.I., at Yurchenko – stretched salto backward with 1/1 turn off.

By analyzing all the gymnasts` vaults, we notice that both the average flight length (PF1 = 1,91m in

2013 and 1.50 in 2014) and the flight height (0,43m, 0,28m in 2013 and in 2014) decreased.

The average values of the body segments trajectories in the horizontal movement shows us a big difference between the two phases of the landing in the two years (0,32m in 2013 and 0,43m 2014).

The results of the performances obtained in competition and the penalties related to the landings, shows a final mark average that is lower by 0,40 points in 2014 and an penalti average of about 0,30 (average error) in the two years. We find that the amount of tenths penalty is 0,40 points higher in 2014, the same difference as between the final marks average, but lower this year.

Conclusions

The biomechanical analysis done by using computerized video method for vault landings performed by the gymnasts, highlighted the progress in accordance with the performances obtained in the competition and their penalties, which confirms the proposed hypothesis by the obtained results.

Following the analysis above, we observe that all the gymnasts have difficulties at landing, losing important tehths in competition. We therefore consider that specific training is required for this phase.

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