

## Original Article

### Biomechanical analysis of skilled female gymnasts' technique in «round-off, flic-flac» type on the vault table

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#### Abstract:

It is important to know the biomechanical characteristics of technique for skilled female gymnasts performing vault group «Round-off, flic-flac» on «vault table». The vaults of 20 skilled female gymnasts – the members of Ukraine's National Team – were filmed using Sony Handicam DCR-VX2100E digital camera (25 frames per second) positioned in line with the table, perpendicular to the direction of the runway. We determined the leading elements of the vault movement structure. There are the biomechanical characteristics of the post-flight phase: time in air, height off the table, horizontal distance from the table, which was confirmed by correlation analysis. Grounding on the results of biomechanical analysis we have developed the training program for skilled female gymnasts in order to improve their «Round-off, flic-flac» vault performance. 20 qualified female gymnasts were divided by random selection into two groups of 10 gymnasts both in control and experimental group. Gymnasts in both groups had no statistically significant differences by biomechanical characteristics of vault technique at the beginning of the pedagogical experiment. Pedagogical experiment was carried out during 12 months at the training to main starting in the Ukrainian and World Championships. Gymnasts in both groups trained on a single plan per 3 hours twice a day, six days a week. Gymnasts performed vaults for 45 minutes as in the experimental and the control group during each training session. The only difference between the groups was that the control group trained under the traditional program and the experimental group trained by our program. The effectiveness of developed program was confirmed by pedagogical experiment. Gymnasts of the experimental group increased «Round-off, flic-flac» vault scores statistically significantly ( $p < 0.05$ ); gymnasts in the control group increased their scores insignificantly ( $p > 0.05$ ).

**Key words:** gymnast, «Round-off, flic-flac», vault table, biomechanical analysis.

#### Introduction

Federation Internationale de Gymnastique (FIG) replaced the traditional vaulting horse with an apparatus «vault table» in 2001. Significant changes in the vaulting apparatus influenced onto the biomechanical structure of gymnast's technique (Naundorf et al, 2008; Sands & McNeal, 2002). Nowadays the technology of biomechanical analysis with motion capture is one of the most perspective methods of methods of the registration of skilled athlete's motor actions. Despite the fact that improving of the vaulting technique of skilled gymnasts is one of the actual problems in the sport training, this problem has not been studied completely from the aspect of biomechanical analysis. The hypothesis of this research was the objective competition data for skilled female gymnasts obtained by biomechanical video and computer technology, may be used in order to increase their training process efficiency.

The aim of this investigation was to determine the biomechanical characteristics of technique for skilled female gymnasts performing vault group «Round-off, flic-flac» on «vault table».

#### Material & methods

We used the following methods: biomechanical video & computer analysis of kinematic characteristics of the vault; pedagogical experiment, statistical methods.

20 skilled female gymnasts – the members of Ukraine's National Team – performed «Round-off, flic-flac» vaults on «vault table». These vaults were filmed using Sony Handicam DCR-VX2100E digital camera (25 frames per second) positioned in line with the table, perpendicular to the direction of the runway. Then video film was processed with IBM computer by «BioVideo» software which has been developed by kinesiology department, National University of Physical Education and Sports of Ukraine. The reading of coordinates of points of the athlete's body was carried out from the stop frame of the recording by developed software. This software was used for obtaining the following biomechanical characteristics: horizontal, vertical and the

resulting linear velocities of the center of mass (CM) and centers of joint rotation of the athlete's body; angular movement and angular velocities of segments. As a model of the human support-motion apparatus a 14-segment, branched kinematical circuit was used, which parts under the geometrical characteristics met to large segments of a human body, and frames of reference met to coordinates of the basic joints (20 points were selected). The vault was divided into seven phases: I – approach phase; II – hurdle-step phase; III – on-board phase; IV – pre-flight phase; V – on-table phase; VI – post-flight phase; VII – landing.

**Results**

We counted the vaults number of different categories performed by artistic women gymnasts in the finals of Olympic Games 2004, World Championships 2005–2006, European Championships 2004–2006 and Ukrainian Championships 2004–2006. As a result we confirmed that the most common vault was «Round-off, flic-flac». The number of «Round-off, flic-flac» vaults was 58 from 144 vaults (40.3 %) performed by 72 women gymnasts in all 18 competitions. We determined that significant number of errors just in gymnast's technique incurred deduction in scoring.

We measured quantitative kinematic characteristics of female gymnast's motor actions at «Round-off, flic-flac» vault on «vault table» (Table 1). The leading elements of the vault movement structure are the biomechanical characteristics of the post-flight phase: time in air, height off the table, horizontal distance from the table, which was confirmed by correlation analysis. The correlation coefficients between these characteristics and vaulting score were  $r=0.50-0.75$ ,  $p<0.05$ .

Table 1. Kinematic characteristics of «Round-off, flic-flac» vault performed by skilled female gymnasts of control (n=10) and experimental (n=10) groups on the «vault table» at the beginning of pedagogical experiment

Phase	Characteristic	Control group		Experimental group		Difference	
		mean	SD	mean	SD		
I	approach phase	velocity, m·s <sup>-1</sup>	5.60	0.56	5.61	0.42	p>0.05
II	hurdle-step phase	time, s	0.146	0.016	0.140	0.013	p>0.05
III	on-board phase	time, s	0.134	0.016	0.144	0.018	p>0.05
		velocity at take-off the board, m·s <sup>-1</sup>	4.74	0.22	4.75	0.26	p>0.05
		knee joint, degrees	163.9	8.2	164.7	8.4	p>0.05
		hip joint, degrees	131.8	9.9	133.0	5.3	p>0.05
IV	pre-flight phase	time, s	0.196	0.022	0.196	0.034	p>0.05
V	on-table phase	time, s	0.164	0.013	0.160	0.013	p>0.05
		velocity at take-off the table, m·s <sup>-1</sup>	3.75	0.30	3.77	0.31	p>0.05
		shoulder joint, degrees	158.5	9.4	158.1	8.8	p>0.05
		time, s	0.862	0.024	0.856	0.018	p>0.05
VI	post-flight phase	height off the table, m	1.33	0.11	1.33	0.10	p>0.05
		horizontal distance, m	2.07	0.24	2.09	0.22	p>0.05
		hip joint, degrees	66.5 (n=2)	4.9	67.0 (n=3)	1.0	p>0.05
	on-piked salto backward off	hip joint, degrees	152.0	5.5	152.2	11.3	p>0.05
	on-stretched salto backward with 1/1 turn (360) off	hip joint, degrees	152.0	5.5	152.2	11.3	p>0.05
Vault total time, s			1.502	0.037	1.498	0.033	p>0.05

We have developed the training program for skilled female gymnasts which was based on the results of biomechanical analysis in order to improve their «Round-off, flic-flac» vault performance. This program consists of seven complexes with special physical exercises which were aimed to the improving the biomechanical characteristics of gymnast's motor actions technique in each vault phase. The effectiveness of the developed program was tested by a pedagogical experiment.

20 qualified female gymnasts – the members of Ukraine's National Team – were divided by random selection into two groups of 10 gymnasts both in control and experimental group. Gymnasts in both groups had no statistically significant differences by biomechanical characteristics of vault technique at the beginning of the pedagogical experiment. Pedagogical experiment was carried out during 12 months at the training to main starting in the Ukrainian and World Championships. Gymnasts in both groups trained on a single plan per 3 hours twice a day, six days a week. Gymnasts performed vaults for 45 minutes as in the experimental and the control group during each training session. The only difference between the groups was that the control group trained under the traditional program and the experimental group trained by our program.

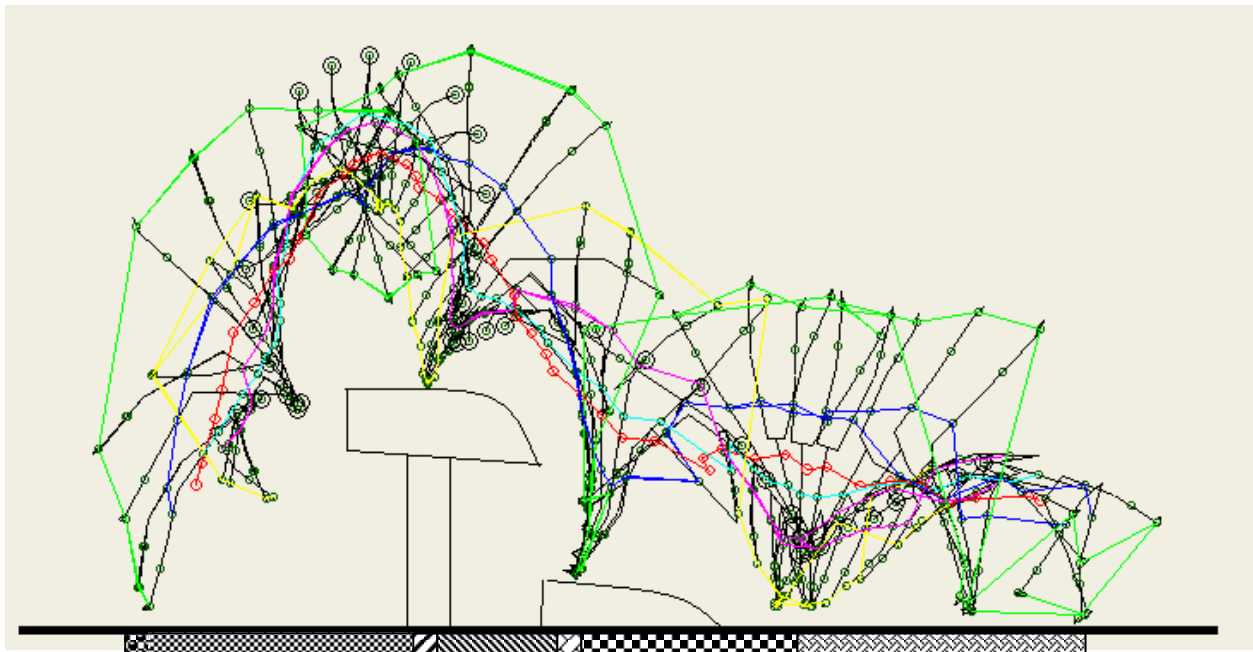
The effectiveness of our training program in the improving of «Round-off, flic-flac» vault performance for skilled female gymnasts was confirmed as a result of the experiment (Table 2).

Table 2. Kinematic characteristics of «Round-off, flic-flac» vault performed by skilled female gymnasts of control (n=10) and experimental (n=10) groups on the «vault table» as a result of pedagogical experiment

Phase	Characteristic	Control group		Experimental group		Difference	
		mean	SD	mean	SD		
I	approach phase	velocity, m·s <sup>-1</sup>	6.93	0.432	7.78	0.379	p<0.05
II	hurdle-step phase	time, s	0.144	0.008	0.134	0.010	p<0.05
III	on-board phase	time, s	0.134	0.013	0.122	0.006	p<0.05
		velocity at take-off the board, m·s <sup>-1</sup>	5.93	0.426	6.45	0.527	p<0.05
		knee joint, degrees	165.00	7.149	175.30	5.618	p<0.05
		hip joint, degrees	134.20	7.685	147.40	5.892	p<0.05
IV	pre-flight phase	time, s	0.180	0.016	0.166	0.013	p>0.05
V	on-table phase	time, s	0.156	0.016	0.138	0.018	p<0.05
		velocity at take-off the table, m·s <sup>-1</sup>	5.29	0.535	5.97	0.470	p<0.05
		shoulder joint, degrees	164.60	7.919	172.40	6.703	p<0.05
VI	post-flight phase	time, s	0.878	0.015	0.896	0.021	p<0.05
		height off the table, m	1.56	0.113	1.72	0.087	p<0.05
		horizontal distance, m	2.34	0.234	2.75	0.204	p<0.05
VI	on-piked salto backward off	hip joint, degrees	60.00 (n=2)	5.657	- (n=0)	-	-
	on-stretched salto backward with 1/1 turn (360) off	hip joint, degrees	159.29	6.873	170.00	5,425	p<0.05
Vault total time, s			1.492	0.032	1.456	0.021	p<0.05

Thus, gymnasts of the experimental group increased on average A score from 4.31±0.31 to 5.05±0.45, p <0.05; B score from 8.63±0.25 to 8.94±0.19, p <0.05; «Round-off, flic-flac» vault score from 12.94±0.54 to 13.99±0.57, p <0.05; gymnasts of the control group also increased A score from 4.41±0.49 to 4.59±0.50, p > 0.05, B score from 8.58±0.39 to 8.65 ±0.34, p > 0.05; vault score from 12.99 ±0.81 to 13.24 ±0.64, p > 0.05.

The biokinematical schemes of the «Round-off, flic-flac» vault performed by female gymnast of the experimental group are presented by Figure 1. Skilled female gymnasts of experimental group won the prizes in competitions of Ukrainian and World Championships.



Phase

a

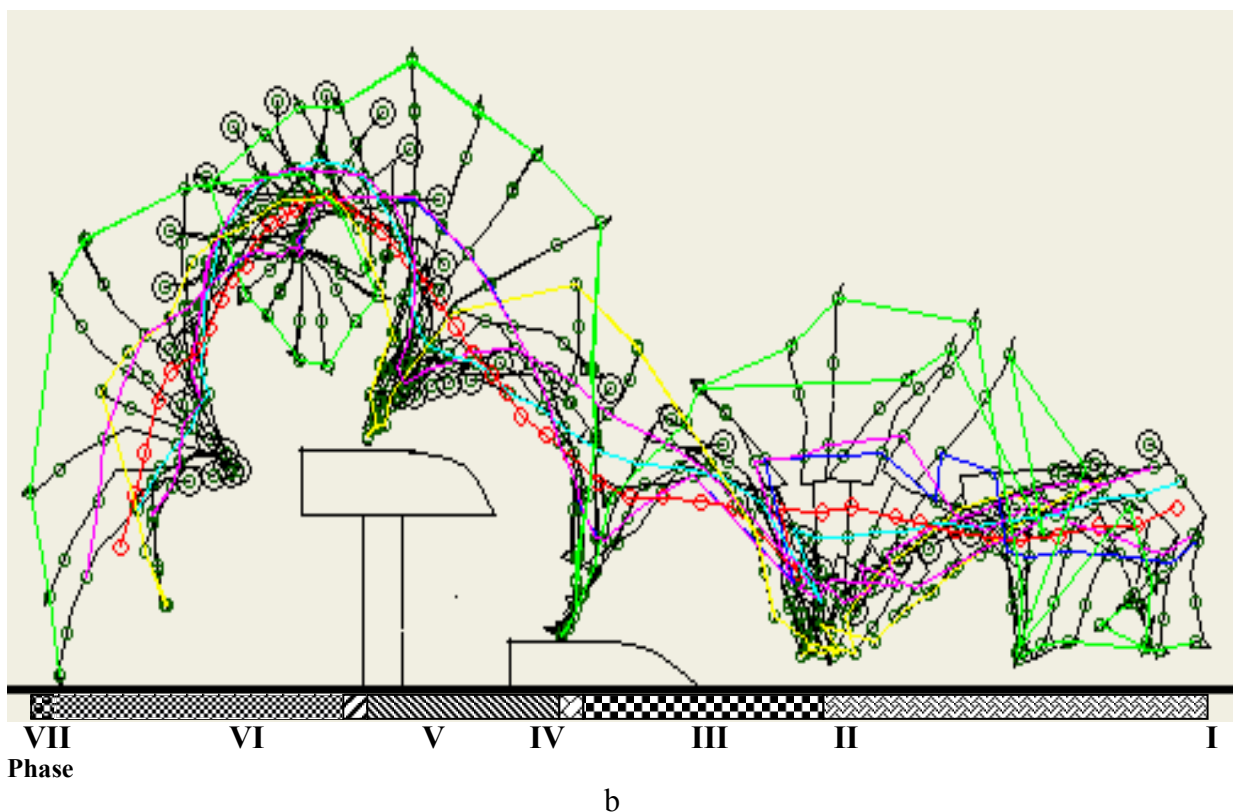


Figure 1. The biokinematical schemes of the «Round-off, flic-flac» vault performed by female gymnast K-k of the experimental group: a – before the pedagogical experiment: I – approach phase (frames 1-10); II – hurdle-step phase (frames 10-13); III – on-board phase (frames 13-17); IV – pre-flight phase (frames 17-22); V – on-table phase (frames 22-26); VI – post-flight phase (frames 26-48); b – after the pedagogical experiment: I – approach phase (frames 1-10); II – hurdle-step phase (frames 10-13); III – on-board phase (frames 13-16); IV – pre-flight phase (frames 16-21); V – on-table phase (frames 21-24); VI – post-flight phase (frames 24-47); recording speed – 25 frames per second

### Discussion

Nelson et al. (1985), found the average horizontal component velocity of gymnasts in a vault over “old horse” at the 1984 Olympics at board contact was 6.5 m/s. Our investigation indicated that skilled female gymnasts showed the average velocity from 6.9 m/s in control group to 7/8 m/s in experimental group at board contact in vault on “new table”. The average velocity of gymnasts in experimental group at take-off the board was 6.5 m/s.

A study by Sands and Cheetham (1986) found the average run-up velocity of female gymnasts was 7.25 m/s on a variety of vaults. Sands and Cheetham also showed a high correlation between vault run-up speed and score ( $r = 0.95$ ,  $p < 0.05$ ). We also received the correlation coefficients between vault run-up speed and total score ( $r=0.94$ ,  $p<0.05$ ) and technique score ( $r=0.72$ ,  $p<0.05$ ).

Knoll & Krug (2002), using a laser speed measurement system for the competition analysis of the women vaults in world championship 2007 found that handspring-type vaults averaged 7.74 m/s, Tsukahara-type vaults averaged 7.54 m/s, Yurchenko-type vaults averaged 7.30 m/s, and Round-Off and  $\frac{1}{2}$  turn vaults averaged 7.60 m/s on the vaulting table. The highest run-up speed recorded by Knoll & Krug, for a female gymnast was 8.37 m/s.

The biomechanical characteristics of skilled female gymnasts motor actions and the laws of their changing in «Round-off, flic-flac» vault allowed to develop a program for performance technique improving. This program includes: strategy, purposes, directions to special exercises complex, selection of training tools and methods, facilitated or complicated execution of motor actions, dosage, recreation intervals, guidance, and 7 exercise complexes for each vault phase, performance criteria and biomechanical monitoring for technique elements.

The program to improve «Round-off, flic-flac» vault performance received the approval in the pedagogic experiment for skilled female gymnasts. Gymnasts of the experimental group increased «Round-off, flic-flac» vault scores statistically significantly ( $p < 0.05$ ); gymnasts in the control group increased their scores insignificantly ( $p > 0.05$ ) (as told in Figure 2).

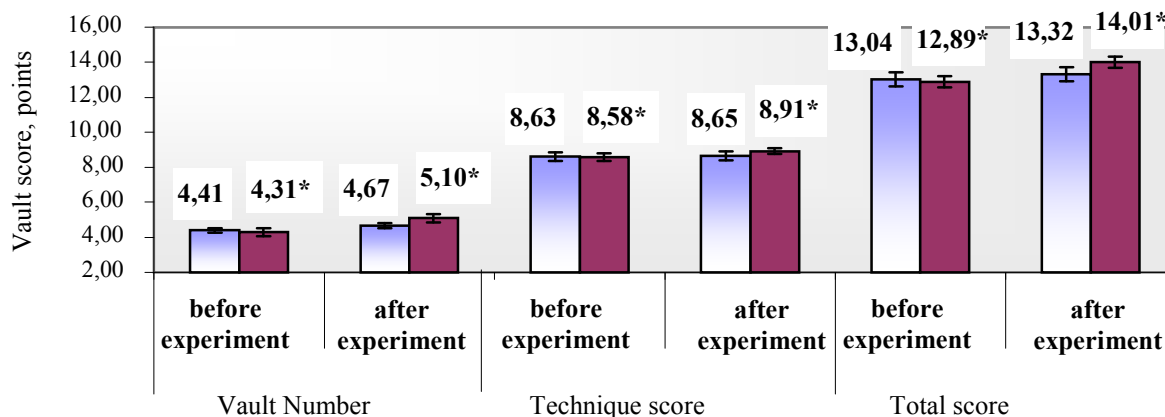


Figure 2. The scores of skilled female gymnasts in the «Round-off, flic-flac» vault during pedagogical experiment

□ - control group; ■ - experimental group; \* -  $p < 0,05$

**Conclusions:**

1. The leading elements of the «Round-off, flic-flac» vault motor structure of qualified female gymnasts on «vault table» are the biomechanical characteristics of post-flight phase: the time in air, height off the table and distance from the table, which was confirmed by correlation analysis.
2. Basing on the results of biomechanical analysis, we have developed the training program for skilled female gymnasts in order to improve their «Round-off, flic-flac» vault performance.
3. The effectiveness of developed program to improve the «Round-off, flic-flac» vault technique for skilled female gymnasts was confirmed by pedagogical experiment.

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