

## Biomechanical Structure of Technique of «Tsukahara» Vaults Performed by Qualified Female-gymnasts

*National University of Physical Education and Sports of Ukraine (Kiev)*

**Introduction.** The implementation of the new table by the FIG has resulted in some necessary adaptations to vaulting and our approach to training of vaulting technique. 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. Significant changes in the vaulting apparatus influenced onto the biomechanical structure of gymnast's technique [2, 4]. The aim of the research was to determine the biomechanical characteristics of technique for skilled female gymnasts performing vault group «Tsukahara» on «new table». This research was carried out according to the «Consolidated Plan research in the field of physical education and sport for 2011–2015» of the Ukrainian Ministry on Family, Youth and Sports Affairs in theme: 2,16 «Improvement of technical and tactical training of skilled athletes with the use of modern technologies for measuring, analyzing and simulation of movements».

**Methodology.** We used the technology of biomechanical analysis of human movement with video recording. The positions of the gymnast's body in movement were recorded by a digital video camera at a speed of 25 frames per second in sagittal plane. 14-segment, branched kinematical circuit was used as a model of the human support-motion apparatus. We calculated the coordinates of gymnast's basic joints (20 points were selected). Then we obtained kinematic and dynamic biomechanical characteristics by «BioVideo» software (developed by the kinesiology department). 20 highly skilled female gymnasts (age 13–15 years) – members of Ukraine's National Team – have been participated in the experiment.

**Results.** The vault was separated into six phases: running approach, board contact, first flight, hand contact, second flight, touch-down. We calculated the horizontal, vertical and resulting linear velocities of the centre of mass and joint rotation centre of the gymnast's body; angular movement and angular velocities of biosegments; potential, kinetic and total energy of separate biosegments and the whole body; work output at take-off; capacity of taking-off.

First of all, hand contact by apparatus is one of the major factors in vaulting biomechanical structure [1, 5]. One of the investigation purpose was to study the features of hand contact phase in vaults under the changed apparatus design: from old horse to new table. From the biomechanical point of view, the hand contact phase in a vault can be carried out by hands faster, and the changed surface of an apparatus will raise capacity of a push hands, flight height and distance of second flight phase. Time of hand contact phase is the following: in «Tsukahara» tucked – 0,38 s compared to 0,22 s, «Tsukahara» stretched – 0,38 s compared to 0,20 s, round-off, flic-flac on – 0,35 s compared to 0,20 s, round-off, flic-flac on-tucked salto backward off – 0,24 s compared to 0,18 s, round-off, flic-flac on-stretched salto backward off – 0,26 s compared to 0,16 s.

We have developed the training program for skilled female gymnasts which was based on the results of biomechanical analysis in order to improve their «Tsukahara» 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 – 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 startings 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 [3].

The effectiveness of our training program in the improving of «Tsukahara» vault performance for skilled female gymnasts was confirmed as a result of the experiment (Table 1). Thus, gymnasts of the experimental

group increased on average A score from  $4,08 \pm 0,10$  to  $4,26 \pm 0,15$ ,  $p < 0,05$ ; B score from  $8,55 \pm 0,15$  to  $8,93 \pm 0,18$ ,  $p < 0,05$ ; gymnasts of the control group also increased A score from  $4,08 \pm 0,10$  to  $4,12 \pm 0,10$ ,  $p > 0,05$ , B score from  $8,51 \pm 0,15$  to  $8,63 \pm 0,23$ ,  $p > 0,05$ .

Table 1

**Kinematic characteristics of «Tsukahara» vault performed on «new table» by skilled female gymnasts of control (n = 10) and experimental (n = 10) groups as a result of pedagogical experiment**

Phase	Characteristic	Control group		Experimental group		Difference	
		$\bar{x}$	S	$\bar{x}$	S		
I	approach phase	velocity, $m \cdot s^{-1}$	6,34	0,609	7,60	0,626	$p < 0,05$
II	hurdle-step phase	time, s	0,284	0,018	0,270	0,014	$p > 0,05$
III	on-board phase	time, s	0,112	0,010	0,094	0,019	$p < 0,05$
		velocity at take-off the board, $m \cdot s^{-1}$	5,52	0,408	6,28	0,393	$p < 0,05$
		knee joint, degrees	156,50	5,701	167,40	8,771	$p < 0,05$
		hip joint, degrees	156,80	5,391	164,20	5,029	$p < 0,05$
IV	pre-flight phase	time, s	0,204	0,008	0,184	0,018	$p < 0,05$
V	on-table phase	time, s	0,236	0,023	0,210	0,025	$p < 0,05$
		velocity at take-off the table, $m \cdot s^{-1}$	4,58	0,305	4,98	0,413	$p < 0,05$
		shoulder joint, degrees	150,70	6,977	160,50	7,075	$p < 0,05$
VI	post-flight phase	time, s	0,816	0,018	0,840	0,019	$p < 0,05$
		height off the table, m	1,38	0,136	1,77	0,137	$p < 0,05$
		horizontal distance, m	2,59	0,093	2,74	0,076	$p < 0,05$
	on-piked salto backward off	hip joint, degrees	71,6	2,5	65,50	1,291	$p < 0,05$
on-stretched salto backward with 1/1 turn (360) off	hip joint, degrees	–	–	150,0 (n = 1)	–	–	
Vault total time, s			1,652	0,034	1,598	0,053	$p < 0,05$

**Conclusions.** The increase in available surface area on the new table over the old horse has improved performance of the vaults by highly skilled female-gymnasts.

The leading elements of the «Tsukahara» vault motor structure of qualified female gymnasts on «new 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.

The effectiveness of developed program to improve the «Tsukahara» vault technique for skilled female gymnasts was confirmed by pedagogical experiment.

The prospects of our research include the modelling of skilled female gymnast's individual technique in «Tsukahara» vault.

#### The List of References

1. Irwin G. & Kerwin D. G. The influence of the vaulting table on the handspring front somersault / G. Irwin & D. G. Kerwin // Sports Biomechanics. – Volume 8. – Issue 2, 2009. – P. 114–128.
2. Knoll, K., & Krug, J. (2002). The vaulting table – a new vaulting apparatus in artistic gymnastics. Retrieved [Electronic resource]. – Mode of access : <http://www.coachesinfo.com/category/gymnastics/61/>
3. Krupenya S., Khmel'nitskaya I. Improvement of sports equipment skilled gymnasts vault on the modified apparatus design / S. Krupenya // Science in the Olympic Sports. –2012. – Vol. 1. – P. 58–67.
4. Naundorf, F. (2008). Development of the velocity for vault runs in artistic gymnastics for the last decade / F. Naundorf // In: Kwon, Y., Shim, J., Shim, J. K., Shin, I. ISBS XXVI Conference. – P. 481–484.
5. Sands, W. A., & McNeal, J. R. (2002). Some Guidelines on the Transition from the Old Horse to the New Table. Technique, 22, 22–25.

#### Annotations

As a result of the analytical problem study it was revealed that due to the significant structural changes of sports equipment for the vault, the transition from the «horse» to «vaulting table», the biomechanical structure of vault technique has been changed. We developed the special programs to improve sports technique for skilled female gymnasts in vault «Tsukahara» with a «vaulting table» which have been based on the biomechanical characteristics of their motor

actions technique. Each of the special programs consist of seven complexes for 5 exercises (a total of 35 exercises). One separate complex solves the problem in achieving the biomechanical parameters on which sport performance depends directly. The efficiency of author's special programs was confirmed through direct comparison of the pedagogical experiment.

**Key words:** technique of motor actions, skilled female gymnasts, «Tsukahara» vault, «vaulting table».

**Ірина Хмельницька, Світлана Крупеня. Біомеханічна структура техніки кваліфікованих гімнасток в опорних стрибках типу «Цукахара».** У результаті аналітичного вивчення проблеми виявлено, що у зв'язку з істотними конструктивними змінами спортивного снаряда для опорних стрибків, переходом від снаряда «кінь» до снаряда «стрибковий стіл» змінилася біомеханічна структура техніки опорного стрибка. Спираючись на результати біомеханічного аналізу кінематичної структури рухових дій гімнасток, уперше обґрунтовано й розроблено спеціальні програми вдосконалення спортивної техніки опорних стрибків типу «Цукахара» для кваліфікованих гімнасток. Кожна зі спеціальних програм складається із семи комплексів по п'ять спеціальних фізичних вправ (усього 35 вправ), у кожному із яких розв'язуються завдання на досягнення тих біомеханічних показників, від яких безпосередньо залежить спортивний результат. Ефективність розроблених спеціальних програм підтверджена за допомогою прямого порівняльного педагогічного експерименту. Результати досліджень упроваджені в практику підготовки національної збірної команди України зі спортивної гімнастики.

**Ключові слова:** техніка рухових дій, кваліфіковані гімнастки, опорний стрибок типу «Цукахара», «стрибковий стіл».

**Ірина Хмельницкая, Светлана Крупеня. Биомеханическая структура техники квалифицированных гимнасток в опорных прыжках типа «Цукахара».** В результате аналитического изучения проблемы установлено, что в связи с существенными конструктивными изменениями спортивного снаряда для опорных прыжков, переходом от снаряда «конь» к снаряду «прыжковый стол» изменилась биомеханическая структура техники опорного прыжка. Биомеханический видеокомпьютерный анализ позволил выявить особенности кинематической структуры техники двигательных действий квалифицированных гимнасток в опорных прыжках типа «Цукахара» на снаряде «прыжковый стол». Основываясь на результатах биомеханического анализа кинематической структуры двигательных действий гимнасток, обоснованы и разработаны специальные программы совершенствования спортивной техники опорных прыжков типа «Цукахара» для квалифицированных гимнасток. Каждая из специальных программ состоит из семи комплексов по пять специальных физических упражнений (всего 35 упражнений), в каждом из которых решаются задачи на достижение тех биомеханических показателей, от которых непосредственно зависит спортивный результат. Эффективность разработанных специальных программ подтверждена посредством прямого сравнительного педагогического эксперимента.

**Ключевые слова:** техника двигательных действий, квалифицированные гимнастки, опорный прыжок типа «Цукахара», «прыжковый стол».