Improvement of Sports Technique Based on Biomechanical Indicators of Yurchenko Handspring Vault in Women's Artistic Gymnastics

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Abstract

The main purpose of this paper is the biomechanical analysis of the kinematic and dynamic indicators of sports technique used in Yurchenko handspring vault by means of the macro methods for exercises learning during the training basic specialization stage. This scientific approach led to the organization of an experimental study, using the research methods as follows: 1. Method of theoretical and methodological analysis of literature related to artistic gymnastics. 2. Method of evaluation of gymnastics exercises sports technique using the algorithmic analysis of the motion. 3. Video computerized method, using" Pinnacle Studio"," Kinovea" and" Physics ToolKit" programs. 3. Method of movement postural orientation and evaluation of key elements of sports technique with complex coordination of movement structure. 4. Method of linear-branched programming of gymnastics exercises learning and improving. 5. Statistical method, by means of" KyPlot" program. The research was conducted from 2012 to 2014, when gymnasts' performances were monitored in three national competitions - handspring vaults event; a number of 7 athletes aged 12 to 15 participated in these competitions, all of them members of junior national team of Romania. The results of the research highlighted and identified the kinematic and dynamic characteristics of sports technique key elements of Yurchenko vault in women's artistic gymnastics. The implementation of the macro methods of learning in young gymnasts' training contributed to the improvement of sports technique and the effective experimental distribution of the difficult and highly difficult basic vaults.

Keywords: kinematics, key elements, dynamics, technical training, performance, vault.

Introduction

Modern artistic gymnastics develops in line with the rules and trends of the world sport. The concept of artistic gymnastics development and improvement, the argumentation of methodology were created throughout the preparation of Olympic cycles, enabling the efficient management of multi-annual sports training (Arkaev & Suchilin, 2004).

In artistic gymnastics, technical training must be very demanding, because the primacy in competitions is determined by the accuracy of movement (amplitude, expressiveness, fluidity of movement a. s. o.). The analysis of technique reveals the following components: *technical element, technical procedure, style and basic mechanism of technical procedure*. Learning any technical procedure is based on models established by specialists following up numerous and thorough studies of biomechanics. The study of technique and the determination of its rules lead to increasing speed of execution, optimal coordination, identification of mistakes etc. (Dragnea & Mate-Teodorescu, 2002).

In this context, it is clear that each one of the modern sports is based on exercises that vary depending on general volume of the material and on specific structure; the problem of motor skills transfer is highlighted differently (Gaverdovkij, 2002, 2007). Biomechanical researches in artistic gymnastics can be performed using biomechanical methods and also 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 recording, processing and analyzing the data obtained (Potop, 2007).

In order to group the gymnastics elements into parts, several criteria can be used, such as pedagogical, psychological, physiological, biomechanical ones 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). Technique analysis relates to the highlighting of biomechanical characteristics and to motion parameters. The biomechanical characteristics are divided into kinematic (spatial, temporal and spatial-temporal) characteristics and dynamic characteristics (force and energy). (Arkaev & Suchilin, 2004).

Numerous studies and researches are scientifically applied for understanding and classification based on the clearly defined field of biomechanical study of gymnastics movements. Bruggmann, 1994, taken after Hochmuth and Marthold, 1987, made the most recent classification of movements in gymnastics. Handspring vaults represent the event with a single basic technical structure and variants of this one. The authors B. Bajin, 1979; G. P. Bruggmann, 1984; Y. Takei, 1984, 1990, 1991, 1992, 1996, 1998; Y. Takei and L. K. Kim, 1992; Li and J. Krug, K. Knoll and Zocher, 1998, examine the elastic parameters of the springboard, the parameters of contact with the floor, the handspring and landing parameters, also the correlation of mechanical variables and the score of the vault (Creţu, Simăr & Bărbuceanu, 2004).

Handspring vaults are the event with a single basic technical structure and variants thereof, the handspring rollover. That is why in most numerous studies and researches on the biomechanical issues of handspring vaults the authors (Boloban & Potop, 2014; Penitente, Sands, & McNeal, et al., 2010) examine the elastic parameters of the springboard, the parameters of contact with the floor, the handspring and the landing parameters, also the correlation between the mechanical variables and the score of the vault. In terms of Yurchenko vaults, most authors (Elliot & Mitcheli, 1991; Kashuba, Khmelnitska & Krupenya, 2012; Koh, Jenning, Elliot & Lioyd, 2003; Penitente, Merni & Fantozzi, et al., 2007; **Potop & Timnea, 2012, Potop, 2015)** address various biomechanical aspects regarding the biomechanical comparison of Yurchenko vault and two associated teaching drills, the improvement of sports technique key elements based on biomechanical analysis, the kinematics of springboard phase, the e-learning by computer video analysis of the key elements of sports technique etc.

In terms of structural relations, existing between movements, we emphasize two aspects of these relations – biomechanical and didactical ones. Researches have shown that there are several types of structural relations of movements, which can pass from an exercise to a similar one during the earning process (" intra-profiles" and" inter-profiles"). These" intra-profile" exercises refer, for example, to 4th group vaults – Yurchenko, while the" inter-profile" exercises are the relations of vaults belonging to different groups (Smolevskij & Gaverdovskij, 1999).

The purpose of the paper is to highlight the dynamics of the kinematic and dynamic indicators of Yurchenko-type handspring vault at 12 to 15 years old gymnasts in training basic specialization stage.

Hypothesis of the paper. We consider that the biomechanical analysis of Yurchenko-type handspring vaults based on the achievement of the macro methods of learning in the case of young gymnasts aged 12 to 15 will contribute to the development of sports technique key elements and to the improvement of movement dynamic and kinematic characteristics.

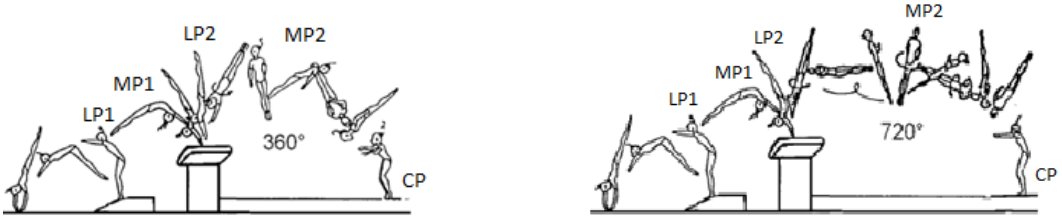
Methodology

The methodological character of this research consists of the generalization and systematization of the large number of scientific data and the practical experience related to knowledge formation. Thus, the macro methods for learning the gymnastics exercises are presented as a modern dynamic system that includes and integrates the technological, didactical, biomechanical and motor structures of the exercises to be learnt. The objective practical-scientific argumentation for elaborating the macro methods to learn gymnastic exercises with increased difficulty was possible thanks to the use of modern theories (Potop, 2015).

This scientific approach entailed an experimental study made within the pedagogical experiment of the post doctoral thesis of the first author, selecting - from the final stage of the research - the dynamics of the biomechanical characteristics of handspring vaults. The research was conducted throughout the period 2012 – 2014, monitoring gymnasts' performances in three national competitions in handspring vaults event. The subjects of the study were 7 athletes of 12 to 15 years old, members of junior national team of Romania. Research methods used: 1. Method of theoretical and methodological analysis of literature related to artistic gymnastics. 2. Method of evaluation of gymnastics exercises sports technique by using the movement algorithmic analysis (Gaverdovschi, 2007). 3. Video computerized method, by means of: "Pinnacle Studio", "Kinovea" and "Physics ToolKit" programs. 3. Method of movement postural orientation and evaluation of key elements of sports technique with complex coordination of movement structure (Sadovski, Boloban & Nizhnikovski, et al., 2009; Boloban, 2013). 4. Method of linear-branched programming of gymnastics exercises learning and improving (Potop, 2015). 5. Statistical method by means of "KyPlot" program.

To highlight the dynamics of the biomechanical characteristics of Yurchenko-type handspring vaults, a number of 11 Yurchenko-type handspring vaults (7 vaults YSS and 4 – YSS 360°) were analyzed in the competitive conditions of the Romanian National Championships, Onești 2012 and other 11 Yurchenko-type handspring vaults (3 handspring vaults YSS, 4 – YSS 360° and 3 – YSS 720°) during the Romanian National Championships, Bucharest 2014.

The phasic structure of the control routines within the research focused on the biomechanical analysis of key elements of Yurchenko round-off vault with backward stretched salto, taking into account the functional structure and the causes as a whole. The biomechanical analysis was made by means of Physics ToolKit Version 6. 0 program, monitoring the key elements of sport technique in preparatory phase – launching posture of the body (LP1), flip off of the springboard (preparatory movement) and multiplication of posture of the body – the 1st flight, half back rollover (MP1) and handspring on apparatus, flip off of the table (LP2); in basic phase – multiplication of posture of the body (MP2), the 2nd flight that highlights the shape of salto and the momentum of maximum height of GCG (1 ½ stretched salto backwards, 1 ½ stretched salto backwards with 360° and 720° turn); and in final phase – concluding posture (CP) of the body, moment of landing damping and freezing (fig. 1).



Round-off, flic-flac on – stretched salto bwd with 1/1 turn (360°) off b) Round-off, flic-flac on – stretched salto bwd with 2/1 turn (720°) off

Note: LP1 – launching body posture 1, MP1 – multiplication body posture 1, LP2 – launching body posture 2, MP2 – multiplication body posture 2, CP – concluding body posture, landing.

Fig. 1. Key elements of Yurchenko vault sports technique

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 National University of Physical Education and Sport from Ukraine, with the subject matters: 2. 11 (Dynamic static stability as a basis for technical training of those involved in sports gymnastics views), 2. 32 (Technical training of qualified athlete based on competitive exercises technique rationalization) and plan of research for 2016 - 2017 of the Faculty of Physical Education and Sport, Ecological University of Bucharest.

Results

The method of video-computerized analysis of Yurchenko-type handspring vaults consistent with the method of movement postural orientation allowed highlighting and identifying the key elements whose assimilation deepens the understanding of sports technique of acrobatic and gymnastics exercises and makes possible the development of modern programs for their learning.

Table 1. Gymnasts' anthropometric and biomechanical indicators necessary for the analysis of sports technique in Yuchenko-type handspring vaults (n = 10)

No.	HS	Statistical indicators*	½ body weight, (kg)	½ body height, arms up, (m)	IR ($kg \cdot m^2$)	RM – GCG, (m)		
						Toes	Shoulders	arms
1	YSS n = 3	$\bar{x}$	17. 78	0. 93	15. 64	0. 732	0. 420	0. 517
		S	2. 04	0. 05	3. 52	0. 07	0. 03	0. 08
		Cv%	11. 46	5. 29	22. 51	9. 70	6. 05	14. 66
2	YSS 360° n = 4	$\bar{x}$	19. 06	0. 96	17. 81	0. 684	0. 368	0. 462
		S	1. 86	0. 05	3. 37	0. 03	0. 02	0. 02
		Cv%	9. 78	4. 75	18. 92	4. 95	4. 98	4. 19
3	YSS 720° n = 3	$\bar{x}$	19. 17	0. 97	18. 29	0. 677	0. 382	0. 469
		S	2. 62	0. 05	4. 25	0. 07	0. 02	0. 03
		Cv%	13. 65	5. 46	23. 32	10. 03	4. 51	7. 35

Note: *indicators were compared with the initial results of the ascertaining experiment of 2012; IR – inertia of rotation = ½ m · ½ r^2 (½ body weight x ½ body height arms up^2)

In table 2 are listed the results of the biomechanical analysis indicators which characterize the kinematic structure of the key elements of sports technique in Yurchenko-type handspring vaults according to joints angles data (by means of «Kinovea» program), executed in conditions of competition during the Romanian National Championships, Bucharest 2014 and the Romanian National Championships of Artistic Gymnastics, Onești 2012.

Table 2. Indicators of angular characteristics of body segments during execution of sports technique key elements in Yurchenko-type handspring vaults

Nr. Crt.	Handspring	Statistical indicator*	LP1, (deg)		MP1, (deg)		LP2, (deg)		MP2, (deg)		CP, (deg)	
			TI	TF	TI	TF	TI	TF	TI	TF	TI	TF
1	YSS 2012, n = 7 2014, n = 3	$\bar{x}$	97. 57	98. 0	92. 86	121. 0	83. 43	66. 67	133. 7	143. 67	126. 0	139. 33
		S	4. 97	5. 57	5. 87	11. 36	3. 99	5. 51	7. 61	2. 08	15. 17	3. 06
		Cv%	4. 91	5. 68	6. 32	9. 39	4. 78	8. 26	5. 69	1. 45	12. 04	2. 19

		t_{i-f}	0. 12		5. 35		5. 49		2. 16**		1. 46**	
		p	>0. 05		<0. 001		<0. 001		>0. 05		>0. 05	
2	YSS 360° 2012, n = 4 2014, n = 4	$\bar{x}$	96. 75	100. 75	90. 5	109. 0	79. 25	72. 5	156. 5	166. 5	97. 75	135. 25
		S	1. 5	2. 06	5. 45	3. 27	7. 54	2. 08	10. 02	7. 77	21. 53	3. 59
		Cv%	1. 55	2. 05	6. 02	3. 00	9. 52	2. 87	6. 40	4. 67	22. 03	2. 66
		t_{i-f}	3. 13		5. 83		1. 72*		1. 58		3. 43	
		p	<0. 05		<0. 01		>0. 05		>0. 05		<0. 05	
3	YSS 720° 2014, n = 3	$\bar{x}$	-	101. 33	-	99. 67	-	71. 00	-	161. 67	-	125. 00
		S	-	1. 53	-	2. 52	-	7. 21	-	14. 43	-	5. 00
		Cv%	-	1. 51	-	2. 53	-	10. 16	-	8. 93	-	4. 00

Note: t_{i-f} - Unpaired Comparison for Means; *p<0, 05; **p<0, 01 (F – Fisher); LP1 – launching body posture 1 – angle between joints of ankle – shoulders; MP1 – multiplication of body posture 1 – angle between toes - shoulders; LP2 – launching body posture 2 – angle between hand joint – foot 2; MP2 – multiplication body posture 2 – angle between hip - torso; CP – concluding body posture, landing– angle between hip – torso

Figure 2 shows the spatial characteristics of the key elements of sports technique used in Yurchenko-type handspring vault according to the data of joints movement trajectories of gymnast O. A-M., 15 years old, executed under the conditions of the Romanian National Championships of Artistic Gymnastics 2012-2014.

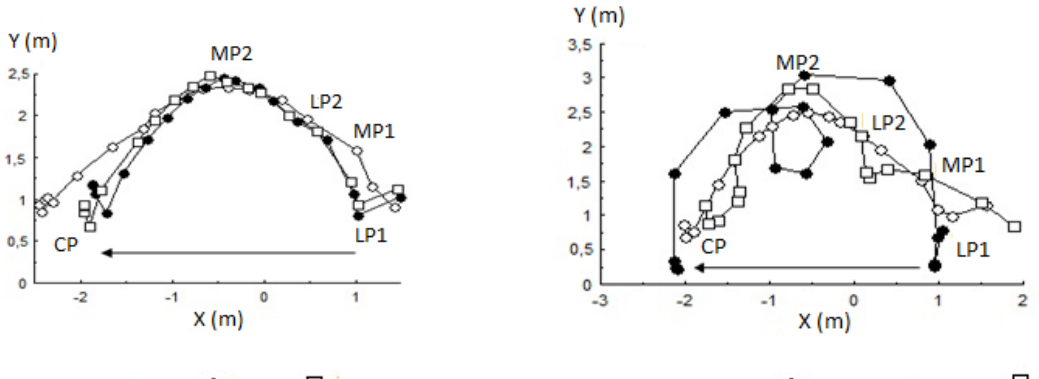
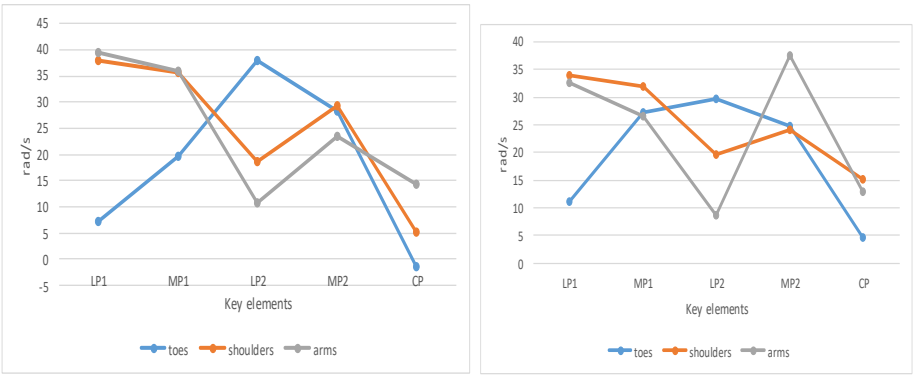


Fig. 2. Graph of body segments trajectories during execution of Yurchenko-type handspring vault, gymnast O. A-M.

Note: LP1 – launching body posture 1, MP1 – multiplication body posture 1, LP2 – launching body posture 2, MP2 – multiplication body posture 2, CP – concluding body posture, landing



2012 b) 2014

Fig. 3. Graphs of body segments angular speed during execution of Yurchenko handspring vault with stretched salto backwards with 1/1 turn (360°), YSS 360°, gymnast O. A-M

Note: LP1 – launching body posture 1, MP1 – multiplication body posture 1, LP2 – launching body posture 2, MP2 – multiplication body posture 2, CP – concluding body posture, landing

Figure 3 shows the graphs of body segments angular speed during the execution of Yurchenko handspring vault with stretched salto backwards with 1/1 turn (360°), of the gymnast O. A-M., 15 years old, executed under the conditions of the Romanian National Championships of Artistic Gymnastics 2012-2014.

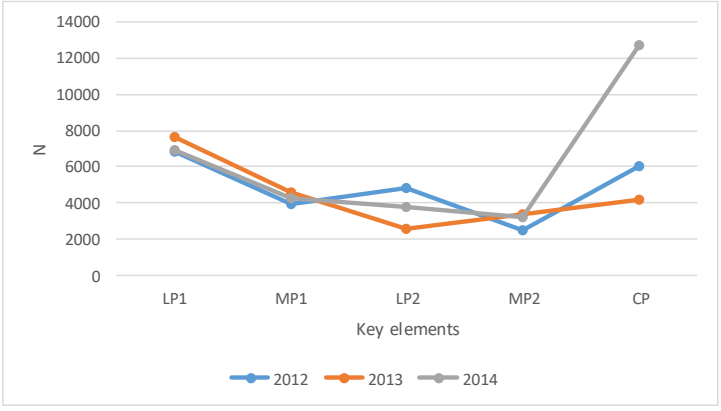


Fig. 4. Graph of GCG force resultant during execution of Yurchenko handspring vault with stretched salto backwards with 1/1 turn (360°), of the gymnast O. A-M., 15 years old

Figure 4 shows the force resultant of GCG displacement during execution of Yurchenko handspring vault with stretched salto backwards with 1/1 turn (360°) of the gymnast O. A-M., 15 years old, under the conditions of the Romanian National Championships of Artistic Gymnastics 2012-2014.

In table 3 are listed the results obtained in competition by the young gymnasts during the Romanian National Championships of Artistic Gymnastics Onești 2012 and Bucharest 2014, handspring vaults event – all around finals and apparatus finals (n = 7).

Table 3. Results obtained by young gymnasts at handspring vaults– Romanian National Championships of Artistic Gymnastics, (n =7)

Statistical indicators	All-around finals, (points)						Apparatus finals, (pts)	
	difficulty		execution		score		results	
	TI	TF	TI	TF	TI	TF	TI	TF
$\overline{x}$	4. 74	5. 08	8. 911	8. 475	13. 64	13. 56	13. 36	13. 28
S	0. 32	0. 70	0. 15	0. 38	0, 36	0, 87	0, 22	0, 16
Cv%	6. 76	13. 78	1. 68	4. 52	2, 61	6, 41	1, 67	2, 62
t_{i-f}	1. 18**		2. 803		0. 221**		0. 57*	
p	>0. 05		<0. 05		>0. 05		>0. 05	

Note: t_{i-f} - Unpaired Comparison for Means, *p<0. 05; **p<0. 01 (F – Fisher)

Table 4. Results of the correlative analysis between the biomechanical indicators of Yurchenko vault and the competitive results in 2014 (n = 7)

№	Indicators		Indicators											
			1	2	3	4	5	6	7	8	9	10	11	12
1	IR (kg·m^2)			0. 558	0. 216	0. 394	0. 691	-	0. 444	0. 318	0. 174	0. 403	0. 076	0. 358
2	RM, (m)	toes	-		*0. 811*	*0. 884*	0. 374	0. 589	0. 120	-	0. 512	-	-	-
3		shoulder	-	-		0. 833	-	0. 670	-	-	0. 757	-	0. 089	-
4		arms	-	-	-		0. 144	0. 702	0. 081	-	*0. 805*	-	-	-
5	KE, (degrees)	LP1	-	-	-0. 020	-		-	0. 669	0. 38	-	0. 339	-	0. 094
6		MP1	-0. 132	-	-	-	-0. 463		-	-	0. 568	-	0. 168	-
7		LP2	-	-	-0. 393	-	-	-0. 237		0. 735	-	0. 507	-	0. 234
8		MP2	-	-0. 341	*-0. 802*	-0. 419	-	-0. 538	-		-	*0. 781*	-	0. 597
9		CP	-	-	-	-	-0. 230	-	-0. 300	-0. 557		-	0. 161	-
10	AA, (points)	difficulty	-	-0. 449	-0. 661	-0. 408	-	-0. 701	-	-	-0. 264		0. 183	*0. 788*
11		execution	-	-0. 057	-	-0. 078	-0. 407	-	-0. 397	-0. 075	-	-		0. 469
12		score	-	-0. 387	-0. 493	-0. 363	-	-0. 491	-	-	-0. 142	-	-	

Note: IR – inertia of rotation, RM – radius of movement of body segments, AA – all-around, r- Pearson's correlation coefficient, p<0. 05, r = 0. 786

Table 4 presents the correlative connections between the biomechanical indicators of Yurchenko-type handspring vaults and the results achieved in the Romanian National Championships, Bucharest 2014.

Discussions

According to the Code of Points, in women's artistic gymnastics the handspring vaults are divided into 5 groups (***FIG, 2013); the round-off stretched salto backward vault (Yurchenko) belongs to group IV. All handspring vaults have one thing

in common, determined by the phases that compose their full development, namely: *running, hurdle onto springboard, first flight, support with hands on table (handspring), second flight and landing* (Vieru, 1997).

One made the analysis and gave the comparative score of sports technique improvement depending on the kinematic and dynamic indicators of Yurchenko-type handspring vaults under the influence of the macro methods of exercises learning during the basic specialization stage (end of the pedagogic experiment 2014) and made the comparison with the beginning and the intermediate stage of the ascertaining experiment and the results achieved in competitions.

The macro methods of learning difficult acrobatic and gymnastics exercises of coordination, also the logical-structural diagram for achievement in sports training are well presented by Prof. V. Boloban (1988). Structurally, the macro methods introduce the functional assembly of long-term programs for learning the exercises of "movement school", the basic level of specialization, of the arbitrary and final programs, also the development of physical qualities consistent with the technical training based on the influence of key concrete goals of gymnasts' sports training (Boloban, 2013).

Results of anthropometric indicators. For the handspring vault (HVT) YSS (n = 3), result of the mean (x; S) ½ of body weight is equal to 7. 78; 2. 04 kg; ½ of body weight, arms up – 0. 93; 0. 05 m; at HVT YSS 360° (n = 4) – ½ of body weight –19. 06; 1. 86 kg; ½ of body weight, arms up – 0. 96; 0. 05 m; la HVT YSS 720° (n = 3) – ½ of body weight 19. 17; 2. 62 kg; ½ of body weight, arms up – 0. 97; 0. 05 m (table 1).

Results of biomechanical indicators, necessary for analyzing the sports technique of Yurchenko-type handspring vault (HVT): the inertia of rotation (IR kg·m^2) of the subjects submitted to research during handspring vaults (HVT) YSS (x; S) is equal to 15. 64; 3. 52 kg·m^2 – increased by 1. 13 kg·m^2 (p>0. 05) in comparison with the data of 2012; HVT YSS 360° – 17. 82; 3. 37 kg·m^2 – increased by 3. 03 kg·m^2 (p>0. 05); HVT YSS 720° – 18. 29; 4. 25 kg·m^2. The radius of movement (RM) of foot joint (ankle) (RM – toes) of the gymnasts during HVT YSS (x; S) is equal to 0. 732; 0. 07 m – increased by 0. 026 m (p>0. 05); HVT YSS 360° – 0. 684; 0. 03 m – increased by 0. 006 m (p>0. 05); HVT YSS 720° – 0. 677; 0. 07 m. The radius of movement of shoulder joint (RM – shoulders) at HVT YSS is equal to 0. 420; 0. 03 m – increased by 0. 001 m (p>0. 05); HVT YSS 360° – 0. 368; 0. 02 m – reduced by 0. 028 m (p>0. 05); HVT YSS 720° – 0. 382; 0. 02 m. The radius of movement of hand joint (RM – hand) at HVT YSS is equal to – 0. 517; 0. 07 m – is reduced by 0. 041 m (p>0. 05); HVT YSS 360° – 0. 462; 0. 02 m – is reduced by 0. 054 m (p<0. 05); HVT YSS 720° – 0. 469; 0. 03 m (table 1).

Handspring vault YSS type (n=3). The result of the mean ($\bar{x}$; S) of the angle between ankle and shoulders joints in body launching posture (LP1) 1 is equal to 98. 0; 5. 57° – is diminished by 0. 43° (p>0. 05) compared to the data of 2012; during multiplication of posture (MP1) of body 1, the angle between ankle and shoulders joints is equal to 121. 0; 11. 36° – increased by 28. 14° (p<0. 001); in launching posture (LP2) of the body 2, the angle of the hand and ankle joints is equal to 66. 67; 5. 51° – reduced by 16. 76° (the execution of "Corbett" was improved) (p<0, 001); in posture multiplication (MP2) of body 2 – angle between hip and torso is equal to 143. 67; 2. 08° – increased by 9. 96° (F; p<0. 01) which characterizes the correction of gymnast's body posture in the concluding posture (CP) of the body – the angle between hip and torso is equal to 139. 33; 3. 06° – increased by 13. 33° (F; p<0. 01), which led to the improvement of vault landing (table 2).

Handspring vault YSS type 360° (n=4). The result of the mean ($\bar{x}$; S) of the angle between shoulders and ankle joints in the launching posture(LP1) of body 1 is equal to 100. 75; 2. 06° – increased by 4. 0° (p<0. 05); in the multiplication of body posture (MP1), the angle between ankle and shoulders joints is equal to 109. 0; 3. 27° – increased by 18. 5° (p<0. 01), which characterizes the high-long flight of the gymnast; in the launching posture(LP2) of the body 2 the angle between hand and ankle joints is equal to 72. 5; 2. 08° – reduced by 6. 75° (F; p<0. 05); in multiplication of posture (MP2) of the body 2, the angle between hip and torso is equal to 166. 5; 7. 77° – increased by 10. 0° (p>0. 05); in the concluding posture (CP) of the body – the angle between hip and torso is equal to 135. 25; 3. 59° – increased by 37. 5° (p<0. 05), which characterizes the improvement of landing quality (table 2).

Handspring vault YSS type 720° (n=3). The result of the mean ($\bar{x}$; S) of the angle between shoulders and ankle joints in the launching posture (LP1) of the body 1 is equal to 101. 3; 1. 53° (the gymnasts-subjects of this research did not execute this vault in 2012); in the multiplication of posture (MP1) of body 1, the angle between ankle and shoulders joints is equal to 99. 67; 2. 52°; in the launching posture (LP2) of the body 2, the angle between hand and ankle joints is equal to 71. 0; 7. 21°; in multiplication of posture (MP2) of the body 2, the angle between hip and torso is equal to is equal to 161. 67; 14. 43°; in the concluding posture (CP) of the body – the angle between hip and torso is equal to 125. 0; 5. 0° (table 2).

Out of 10 handspring vaults, the gymnasts had 3 vaults with steady landing, 4 vaults with hopping at landing and 3 vaults with unsteady landing.

The results of the comparative analysis indicators of spatial-temporal characteristics of sports technique key elements used in Yurchenko-type handspring vaults (YSS 360° and YSS 720º), according to the data of joints movement trajectories of the gymnast O. A-M., aged 15, executed under the conditions of Romanian National Championships of Artistic Gymnastics 2012-2014, are shown in figure 2, duration of the handspring vault YSS 360°- equal to 0. 5 sec ± 0. 033 sec. In the case of YSS 360° vault, during the execution of launching posture (LP1), the body posture before flipping off of the springboard has the torso inclination backward smaller by 5° than the inclination in 2014 (ankle-shoulders angle - 101°), as in the same vault – 2012; multiplication of posture (MP1) of the body 1 in ½ backward rollover higher and farther – GCG – 1. 816 m, in 2014; the launching posture (LP2) of the body 2 – has extension of the torso for legs braking for the supporting Corbett (from handstand) – angle – 70°, in 2014; multiplication of posture (MP2) of body 2 – raising of body GCG by 0. 086 m (2. 479 m) more than in 2012, the angle between hip and torso is equal to 157° (2014); concluding posture (CP) of the body – farther landing in 2012 – 1. 905 m, with improvement of body posture CP in 2014 by 47°, the angle hip - torso is equal to 131°.

In the case of YSS 720° vault (figure 2), during the body posture LP1 execution, the body inclination backwards before flipping off of the springboard is 101° (angle between ankle and shoulders); multiplication of posture (MP1) of body 1 (positioning of body GCG) in ½ rollover backwards lower and longer – 1. 513; 0. 784 m, in comparison with its execution in apparatus finals in the second handspring vault YSS 360° in 2014; launching posture (LP2) of the body 2 – posture with slight extension of the torso for legs braking in the supporting Corbett (from handstand) – angle – 77°; multiplication of posture (MP2) of body 2 – raising of body GCG higher by 0. 020 m (2. 499 m), that the YSS 360° in 2014, the hip-torso angle is equal to 180°; concluding posture (CP) of the body – farther landing – 2. 096 m, compared to YSS 360° in 2014, the hip-torso angle is equal to 109°.

Results of the individual indicators of angular speed and force resultant of the gymnast OA-M (fig. 3 and 4). In 2014 the force resultant of GCG at LP1 during handspring vault (HVT) YSS 360° is equal to 6920 N – increased by 90 N, in comparison with the indicators of 2012, YSS 720° - 8920 N; the angular speed at LP1 YSS 360° in ankle joints is equal to 11. 168 rad/s – increased by 3. 953 rad/s, YSS 720° – 8. 204 rad/s, the angular speed at LP1 YSS 360° in shoulders and hand joints decreased by 6. 748 and 3. 723 rad/s, YSS 720° – 33. 426 and 38. 79 rad/s; MP11 at YSS 360° – the force resultant of GCG in ½ rollover backwards is equal to 4270 N – increased by 310 N, at HVT YSS 720° – 3180 N; the angular speed in ankle joint at HVT YSS 360° – equal to 27. 188 rad/s – increased by 7. 416 rad/s, at HVT YSS 720° – 26. 189 rad/s, the angular speed helped the gymnast to guide effectively the Corbett part LP2; the key element LP2 – posture of gymnast's body for flipping off of apparatus (force resultant of GCG) at HVT YSS 360° and YSS 720° was improved – 3750 and 4350 N; the angular speed at HVT YSS 360° in ankle joint is equal to 29. 816 rad/s – decreased by 8. 051 rad/s, in all vaults the gymnast has the hand joint indicators – 8. 634 – 10. 792 rad/s; the key element MP2 –maximum height of GCG raising (force resultant) was recorded at the gymnast who executed HVT YSS 360° equal to 3200 N – increased by 700 N and in HVT YSS 720° – 3320 N; the angular speed in ankle joint at HVT YSS 360° – 24., 886 and 29. 058 rad/s, in shoulders – 24. 164 and 26. 142 rad/s (the bigger angular speed in angle joint in both HVT allowed a more effective execution of the rotation and preparation for landing); the force resultants of GCG in the key element (CP) at HVT YSS 360° and YSS 720° are – 12700 and 10300 N; the angular speed in shoulders and ankle joints in HVT YSS 360° has the indicators 4. 751 and

15. 289 rad/s, which help to complete the rotation effectively in the salto and to take the comfortable concluding posture for landing; in HVT YSS 720° these indicators are almost similarly equal to 5. 101; 5. 841 rad/s which enabled the gymnast to have a steady landing.

Comparative analysis of the performances achieved in competition (table 3). In 2014 the competitions were attended by 7 gymnasts who executed four types of handspring vaults: YSS, YSS 360°, YSS 720° and Tsukahara with stretched salto – their difficulty corresponds to 4. 400 points, 5. 000 points, 5. 800 points and 4. 600 points. The average difficulty score ($\bar{x}$; S) in the all-around competition is equal to 5. 086; 0. 70 points – it increased by 0. 34 points (for comparison, in 2012 is equal to 4. 743; 0. 32 points). In 2014 the average score for execution – 8. 475; 0. 38 points, it decreased by 0. 436 points, because the gymnasts performed more difficult handspring vaults, but there are significant differences ($p<0.05$); in 2014 the general score – 13. 561; 0. 87 points, decreased by 0. 08 points (F; $p<0.01$), compared with the year 2012, which also certifies the execution of handspring vaults of high difficulty and the omission of technical mistakes. The analogical results obtained in the apparatus finals event. The gymnast O. A. -M. shared the 3rd place with the gymnast SȘ – 13. 312 points; the gymnast CA who executed two vaults belonging to groups of different difficulty (YSS 360° and Tsukahara) was ranked the second, the gymnast ZS – was ranked the 6th. In this competition, the first place was taken by the finalist in the Olympic Games, the gymnast L. I.

Results of correlative analysis (table 4): there were recorded strong connections of the indicators at $p<0.05$ between the radius of movement (RM) of ankle joints and the RM of shoulders and hand joints; the RM of shoulders and RM of hand; the RM of hand and the hip-torso angle in the concluding posture (CP); the RM of shoulders and the angle of ankle and shoulders joints in MP1; hip-torso angle and the score for difficulty of vault; the vault difficulty and the final score of the vault.

Conclusion

The method of video-computerized analysis of Yurchenko-type handspring vaults, consistent with the method of movement postural orientation, helped to highlight, identify and evaluate the key elements of sports technique and the development of modern programs for their learning.

The results of the biomechanical indicators required by the analysis of sports technique specific to Yurchenko-type handspring vault reveal the increase of the value of rotation inertia and the diminution of movement radius in the joints of ankles, shoulders and hands.

The comparative biomechanical analysis of the angular characteristics of sports technique key elements used in Yurchenko-type handspring vaults executed by gymnasts of 12 to 15 years old highlights modifications of the angular values of body posture within movement phasic structure and significant differences between tests.

The introduction of the individual indicators regarding the increase of force resultant of GCG displacement and the angular speed of rotation movement of ankle, shoulders and hands joints compared to the initial values led to a more correct and effective execution of the key elements, which contributed to the improvement of sports technique used in Yurchenko-type handspring vaults.

The comparative analysis of the performances achieved in competitions reveals the type of executed vaults, the increase of the score for vaults difficulty, the diminution of the score for execution and the average score; even if the gymnasts executed more difficult vaults, the ratio between difficulty and execution did not influence positively the final score.

The biomechanical analysis of the Yurchenko-type handspring vaults based on the macro methods for teaching the young gymnasts aged 12 to 15 contributed to the development of sports technique key elements and to the improvement of the kinematic and dynamic characteristics of the movement, which confirms the proposed hypothesis of the paper.

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