Original Article

Comparative biomechanical analysis of key elements in stretched salto backward Yurchenko vault

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Abstract

The main goal of this paper is the comparative biomechanical analysis of stretched salto backward Yurchenko vault, as for the characteristics of key elements of sports technique consistent with the biomechanical indicators of these ones. For this, we considered that the biomechanical analysis of stretched salto backward Yurchenko vault would highlight the characteristics of key elements and the influence of biomechanical indicators on the correct execution of vault technique. The study was conducted from 6 to 7.07.2012 in the Sports Hall of Bucharest, during the accommodation workouts of the International Competition of Romania, the competitive period for the Olympics in London. The research aimed to analyze the biomechanics of stretched salto backward Yurchenko vault of group IV, which is a basic exercise (profile) for performing the higher difficulty vaults belonging to the same group (salto with 360° or 720° twist). The study results emphasize the comparative biomechanical analysis of key elements of stretched salto backward Yurchenko vault, applied to two senior gymnasts, members of the Romanian Olympic Team. The biomechanical analysis was performed by means of a specialized program Physics ToolKit Version 6.0, monitoring the key elements of sports technique (as per Boloban, V., 1990): *start position* of the body (SP), *multiplication of body position* (MP) and *final position* (FP) of the body.

The biomechanical characteristics of video analysis of stretched salto backward Yurchenko vault highlights the duration of key elements, the trajectories of body segments, the height and length of flight II and the influence of biomechanical indicators (velocity and force) upon the correct execution of the vault.

The characteristics of key elements of the analyzed technical structure highlight differences of girl gymnasts' anthropometric measurements while the height and length of flight depends on gymnasts' values of velocity and horizontal and vertical force. The biomechanical analysis of stretched salto backward Yurchenko vault pointed out the characteristics of key elements and the influence of biomechanical indicators upon the technical execution of the vault, which confirms the hypothesis proposed and the performances achieved in competition.

Key words: biomechanics, learning, parameters, vaults, technique.

Introduction

Artistic gymnastics develops in accordance with the trends of performance sport, but it has its specific features, 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 (financial, technical - material, methodical-scientific, biological-methodical, psychological, informational and motivational components) (Arkaev, Suchilin, 2004, p.22).

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 highlights the following components (Dragnea, 1996; Dragnea, Mate- Teodorescu, 2002, p.281): *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. Video and audio devices, located in various positions to cover all trajectories of the body and their segments are highly important for the analysis of the technique. The study of technique and the determination of its rules results in increasing speed of execution, optimal coordination, identification of mistakes, etc. (Dragnea, Mate-Teodorescu, 2002, p.292).

Mistakes may occur throughout the learning or improvement of gymnastics movements. In these cases, things can not be allowed to continue in this way (Vieru, 1997, p.36). Practice has shown that if the small mistakes are not removed in due time, then they have the tendency to join the technical structure and to transform themselves into a big mistake. Technical mistakes are divided into: *systematic, random and typical ones* (Arkaev, Suchilin, 2004, p. 243).

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, p.5).

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 recording, processing and analyzing the data obtained (Potop, 2007, p.140).

The general problem in the study of movements is the assessment of forces application for achieving a high efficiency, efficiency that is given by the way to use energy (Grigore, 2001, p.63).

Due to the impressive dynamics of gymnastics competition, at the present moment the number of technical elements created by the great male and female champions, who distinguished themselves during this period, increased considerably, some of them taking the coded names that reflect the biomechanical characteristics, besides the names of the athletes who executed them with unique virtuosity (Endo, Drăgulescu, Zurchenko, Tsukahara, Milošević, Comănechi, Șuşunova, etc.) (Nicu, 1993, p.258).

In this context it is clear that each one of the modern sports is based on exercises that vary depending on the general volume of the material and on the specific structure; the problem of motor skills transfer is highlighted differently (Gavardovskij, 2007, p.308).

Numerous studies and researches are scientifically applied for understanding and classification based on the clearly defined field of biomechanical study of gymnastics movements. The most recent classification of movements in gymnastics was made by Bruggmann, 1994, taken after Hochmuth and Marthold, 1987 (Cretu, 2004, p.17).

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 support and the landing parameters, also the correlation of mechanical variables and the score of the vault (Cretu, 2004, p.19).

In the last decade came this modality to perform, in the last part of the impetus, the hurdle onto springboard too, by executing the round-off. This modality has the advantage that gymnast's body lay in a position favorable for backward handspring (flick-flack). The most important moment is the handspring on the apparatus, that should be done exactly in handstand(vertically forward), the arms placed as an extension of the torso in order to make possible the support reaction through body's centre of gravity (CGC). From this specific moment, all variants of handspring vaults can be performed (tucked, piked, stretched, 360°, 540°, 720° or 900° twist) (Vieru, 1997, p.238). These vaults belong to the 4th group called Yurchenko (Smolevskij, Gavardovskij, 1999, p.260). If the female gymnast makes a 180° turn after round-off as soon as she takes off from the springboard, she will turn face towards the vaulting table and she will be able to execute afterwards a forward handspring with forward salto (tucked, piked or stretched with 180° or 360° twist. These vaults belong to the 5th group of vaults table in the Code of Points. Three systems of coordination are used in the biomechanical analysis. One of them – fixed or inertial, which is usually related to gymnastics apparatus, and the other two – mobile (non - inertial), related to athlete's body. 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, p.166).

In terms of structural relations, existing between movements, we emphasize two aspects of these relations – biomechanical and didactical. Researches have shown that there are several types of structural relations of movements, which can pass from an exercise to a similar one during learning process. All types of structural relations can be divided into three classes according to the reason of the profile movement. Emerging from the meaning of the profile exercises, one can establish two main classes of structural relations – "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, Gavardovskij, 1999, p.125). The aim of the study is the comparative biomechanical analysis of Yurchenko vault with backward stretched salto, in terms of characteristics of key elements of sports technique in conformity with the biomechanical indicators of these ones.

Hypothesis of the study. We believe that the biomechanical analysis of Yurchenko vault with backward stretched salto will highlight the characteristics of key elements and the influence of biomechanical indicators on the correct execution of vault technique.

Material & methods

The study was conducted from 6 to 7.07.2012 in Sports Hall of Bucharest, within the accommodation training sessions of the International Competition of Romania, during the competitive period for the Olympic Games in London. Recordings were made by means of a digital video camera "Panasonic", monitoring the evolutions of Romanian female gymnasts throughout the accommodation training sessions and competition. The research aimed to analyze the biomechanics of Yurchenko vault with backward stretched salto of 4th group, which is a basic exercise (profile) for the execution of higher difficulty vaults belonging to the same group (360°

or 720° twist salto). The phasic structure of the control exercises 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 (Boloban, 1990; Sadovskij, et. al, 2010). The biomechanical analysis was made by means of Physics ToolKit Version 6.0 program, monitoring the key elements of sport technique in preparatory stage – *start position* of the body (SP), flip off of the springboard (preparatory movement) and handspring (flip off of the table); in basic stage – *multiplication of position* of the body (MP), flight II that highlights the shape of salto and the momentum of maximum height of CGG; and in final stage – *final position* (FP) of the body, moment of landing damping and fixing.

Two female gymnasts were compared during this analysis (I.L. and P.C.), of different age and competitive experience (16 years old and 25 years old), each one performed 2 control vaults during the warm-up for the competition vaults.

Subjects, NP	Age, years	Weight, kg	Height, m
IL	16	36	1.47
PC	25	50	1.62

Figure no. 1. Round-off, flick-flack on – stretched salto backward off (VD – 4.40 P.)

Figure no. 1 shows the program of video biomechanical analysis "Physics ToolKit" of the vault through round-off – backward flick-flack, stretched salto backward (Yurchenko), highlighting CGG trajectory, the analysis parameters : scale, table, frames, working bars, etc.

Results

Table no. 1. Results of biomechanical indicators of key elements in stretched salto backward Yurchenko vault

Subjects, NP	Times, sec	Key elem.	Artic.	Position (m)			Velocity (m/s)			Force (N)		
				X	Y	R	V _x	V _y	V	F _x	F _y	F
IL	0.1	SP	CGG	0.00	2.086	2.086	-6.753	7.563	10.139	1.03E+0.3	-1.33E+0.3	1.68E+0.3
			Vf.P.	0.374	2.746	2.771	-26.742	19.719	33.226	-6.19E+0.3	-2.25E+0.3	2.34E+0.4
			A.U.	-0.018	1.765	1.765	-1.891	4.592	4.966	1.92E+0.3	4.42E+0.3	4.82E+0.3
PC	0.1	SP	CGG	0.326	2.264	2.288	-7.136	9.331	11.747	1.66E+0.3	-3.12E+0.3	3.53E+0.3
			Vf.P.	0.417	3.061	3.089	-38.698	6.038	39.166	-3.53E+0.3	-2.55E+0.4	
			A.U.	0.217	1.757	1.77	0.823	9.606	9.641	3.95E+0.3	9.56E+0.3	1.03E+0.4
IL	0.167	MP m.H.F	CGG	-0.624	2.425	2.504	-9.995	1.351	10.085	1.92E+0.3	-4.71E+0.3	5.09E+0.3
			Vf.P.	-1.105	1.925	2.22	-1.08	-17.018	17.052	1.86E+0.4	8.99E+0.3	2.06E+0.4
			A.U.	-0.232	2.425	2.436	-8.374	11.615	14.319	-6.92E+0.3	-4.71E+0.3	8.38E+0.3
	0.367	MP	CGG	-2.211	1.177	2.504	-8.374	-13.236	15.662	884.036	-3.83E+0.3	3.93E+0.3
			Vf.P.	-2.442	0.517	2.497	0.81	-21.07	21.085	1.61E+0.4	-3.09E+0.3	1.64E+0.4
			A.U.	-1.854	1.426	2.339	-11.345	-3.782	11.959	-6.34E+0.3	2.95E+0.3	6.99E+0.3
PC	0.167	MP m.H.F.	CGG	-0.235	2.681	2.691	-7.685	-0.274	7.69	2.29E+0.3	-5.41E+0.3	5.87E+0.3
			Vf.P.	-0.942	2.228	2.419	14.272	-12.899	24.314	2.74E+0.4	8.52E+0.3	2.87E+0.4
			A.U.	0.199	2.681	2.688	-11.527	11.802	16.497	-1.35E+0.4	-6.86E+0.3	1.52E+0.4
	0.367	MP	CGG	-1.685	1.83	2.487	-8.508	-15.095	17.328	1.25E+0.3	-1.87E+0.3	2.25E+0.3
			Vf.P.	-2.427	1.648	2.934	-2.745	-32.66	32.775	1.93E+0.4	3.33E+0.3	1.96E+0.4
			A.U.	-1.25	1.793	2.186	-7.959	-4.666	9.226	-8.73E+0.3	-1.87E+0.3	8.93E+0.3
IL	0.4	FP	CGG	-2.371	-0.874	2.527						
			Vf.P.	-2.442	0.321	2.463						
			A.U.	-2.3	1.266	2.625						
PC	0.4	FP	CGG	-2.047	1.177	2.361	-7.136	-13.723	15.467	3.95E+0.3	1.25E+0.3	1.31E+0.3
			Vf.P.	-2.264	0.399	2.299	2.47	-18.937	19.098	1.66E+0.3	2.62E+0.3	2.63E+0.3
			A.U.	-1.685	1.522	2.27	-10.704	-6.312	12.426	1.46E+0.3	6.24E+0.3	6.41E+0.3

Note: SP- start position; MP – multiplication of position; FP –final position; m.H.F.- maximum height of flight II; Elem. – elements; artic.= joints; CGG (hip) –general center of gravity; T. – toes; SJ – shoulders joint.

In table no. 1 are shown the results of biomechanical indicators of key elements of stretched salto backward Yurchenko vault, executed by two athletes, I.L. and P.C., both gymnasts being members of Romanian national team. The analysis focused on the times corresponding to the key elements of sports technique,

regarding the start position (SP), multiplication of position (MP) and final position (FP); the analyzed joints, the CGG, toes and shoulders have the horizontal (X) and vertical (Y) values and the resultant of these ones. Also, to point out the influence of biomechanical indicators on the technical execution, we exemplified the velocity and force of segments in various moments of the movement.

Graph no.1. Trajectories of body segments of I.L. athlete

Graph no. 2. Trajectories of body segments of P.C. athlete

In graphs no.1 and 2 are shown the trajectories of body segments in terms of vertical displacement (Y) of the athletes under study.

Discussions

According to the Code of Points, in women's artistic gymnastics the handspring vaults are divided into 5 groups (**FIG, 2009); 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, p.225). In order to perform a correct Yurchenko vault with stretched salto backward we must take into consideration the following *Specific Mistakes of Execution* (**FIG, 2009): in *Flight I*, wrong technique: pelvic angle; arched body, bent knees, legs (knees) apart (0.10- 0.50 P.); *Push-off phase*, wrong technique (successive/alternative support of hands in vaults with flight I forwards, bent arms, shoulders angle, lack of passage in vertical position; longitudinal twist started too early (0.10 – 0.50 P.); *Flight II*, height, accuracy of longitudinal twists, body position (the stretched body position is not maintained, insufficient or late extension, bent or straddled legs (knees) (0.10 -0.50 P.); *Landing*, insufficient length and *General mistakes*: sub-rotation in vaults (without fall, with fall), insufficient dynamism.

Regarding the characteristics of key elements of biomechanical indicators of stretched salto backward Yurchenko vault, we can highlight the following matters:

- in S.P. (start position), *handspring on table*, the trajectories of body segments of the athlete I.L., unlike the gymnast P.C., have the shoulders over the origin vertical in the middle of the apparatus -0.018m; as for the execution velocity at this moment, the highest values are at toes level (T), whose horizontal velocity (V_x) of the athlete IL is higher -26.742 m/s and the vertical velocity is 19.719 m/s while in the case of the athlete PC the horizontal velocity is -38.698 m/s and the vertical velocity is 6.038m/s. These values ensure the push-off of the table, which contribute to the height or length of flight II of the vault; also, the execution force of body segments is higher at toes level (T) in the case of the athlete I.L., namely -6.19E+0.3 N as for horizontal velocity and -2.25E+0.3 N as for the vertical velocity, while the values for the athlete P.C. are -3.35E+0.3 N for the horizontal velocity and -3.35E+0.4 N for vertical velocity.

- in PM.(position of multiplication), *phase II of vault flight* at the interval (0.167 sec- 0.367 sec.), we point out the momentum of maximum height of CGG (hip) at 0.167 sec. of gymnast I.L., namely 2.425m over

the table, while the athlete P.C. has 2.681m, having values almost equal of velocity resultant and vertical velocity at toes (T): athlete I.L. has -17.018m/s while athlete P.C. has higher values of the horizontal velocity, namely 14.272m/s and increases of velocity resultant of 24.314m/s. As for the values of toes (T) horizontal velocity, the athlete I.L. has 1.86E+0.4N and the athlete P.C. has 2.74E+0.4N. These values made possible the rotation of backward salto around the transversal axis of CGG (hip), followed by the moment of landing damping at 0.367 sec. when vertical velocity values increase significantly at both athletes, being almost equal to their resultant in the case of the athlete I.L. , namely -21.07m/s, while the athlete P.C. has -32.66m/s.

- FP (final position), landing – at the momentum 0.4 sec. we notice the vault length (flight II) of the athlete I.L. is -2.442m while the athlete P.C. has -2.264m. The values CGG and T. are close in the case of vertical travel of velocity and force of the athlete P.C., who made a jump (“hopping”) while landing. This is an important action for preparing the turns of the body in longitudinal axis for 360- 720 ° twists vaults.

Conclusions

The study results emphasize the comparative biomechanical analysis of key elements of stretched salto backward Yurchenko vault, applied to two senior gymnasts, members of the Romanian Olympic Team.

The biomechanical analysis was performed by means of a specialized program Physics ToolKit Version 6.0, monitoring the key elements of sports technique (as per Boloban, V., 1990): in the preparatory phase - *start position* of the body (SP), push-off of the springboard (preparatory movement) and handspring (push-off of the table) ; in basic phase - *multiplication of body position* (MP), Flight II highlighting the shape of the vault and *final position* (FP) of the body, moment of damping and fixation of the landing.

The biomechanical characteristics of video analysis of stretched salto backward Yurchenko vault highlights the duration of key elements, the trajectories of body segments in terms of CGG (hip, toes and shoulder joints), the height of flight II in CGG, the length of flight II and velocity and force of the body segments that influence the correct execution of the vault. The characteristics of key elements of the analyzed technical structure point out the differences of gymnasts’ anthropometric measurements. The height and length of the flight depends on gymnasts’ values of horizontal and vertical force and velocity.

The biomechanical analysis of stretched salto backward Yurchenko vault highlighted the characteristics of key elements and the influence of biomechanical indicators upon the technical execution of the vault, which confirms the hypothesis proposed and the performances achieved in competition.

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