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CORRELATIVE ANALYSIS OF BIOMECHANICAL
CHARACTERISTICS OF ACROBATIC ELEMENTS IN FLOOR
EVENT

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Abstract

The aim of this paper is to highlight the degree of connection between the kinematic and dynamic characteristics of sports technique used in double back somersault and the performances achieved by junior female gymnasts in floor events. For this purpose, we used the following research methods: computerized video method through the “Pinnacle Studio”, “Kinovea” and “Physics ToolKit” programs, method of movement postural orientation and evaluation of sports technique key elements with complex coordination of movement structure and statistical-mathematical method. The execution of double back somersault by junior female gymnasts aged 12 to 15 years was analysed using the specialised Physics ToolKit program in order to highlight the kinematic and dynamic characteristics of sports technique key components. To make this correlative analysis following the biomechanical analysis of double back somersault on floor, we selected the most effective biomechanical indicators of movement execution. The study results prove that the comparative correlative analysis (made by parametric and nonparametric statistical methods) of the biomechanical characteristics and the performances achieved in competition by junior female gymnasts reveal different degrees of connection of the analysed indicators and their relationship according to the kinematic and dynamic particularities of sports technique used in double back somersault on floor.

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Keywords: Gymnastics, biomechanics, statistics, sports technique, performance.



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1. Introduction

Nowadays, there is an increase in sports performance; the sports branches have outlined more precisely their training methodology, while the content of modern athletic training has become more complex, more comprehensive and dynamic. The essential aspects of modern sports training addressed in the preparation of athletes highlight: the technique of execution, the applied technique, the ability to integrate the technique into a specific tactical system, the capacity for effort, the mental, theoretical and artistic activity, as well as the athlete's biological activity for competition (Dragnea et al., 2006).

The attainment of sports mastery must be viewed from the perspective of ensuring a solid technical basis. Each sport has an accepted level of perfect technique to which every coach and every athlete aspire. A model must be biomechanically correct and physiologically efficient in order to be widely accepted (Bompa, 2002; Crețu & Potop, 2010).

The technique represents the totality of motor actions performed in an accurate biomechanical framework and according to certain well-defined rules. Technical training consists of all measures taken in terms of methods, methodology and organization throughout the training process in order to assimilate the execution technique specific to each sports branch (Simion, Stănculescu, & Mihăilă, 2011, pp. 122-123).

Technical training cannot be studied separately, but should be seen as a component part of a unitary whole in which technical decisions are correlated with the physical, mental, tactical possibilities of the athlete and the external environmental conditions (Triboi & Păcuraru, 2013). Thus, poor physical training of the athletes leads to a wrong, faulty technique and therefore to failure in competition. Also, good technical and physical training, in the absence of proper mental training, results in modest performance (Grigore, 2001).

Through its rich and particularly varied content, the floor is the longest event (in terms of time), has high dynamism and a spectacular character. The content of floor routines includes a great variety of (dynamic and static) movements, predominantly acrobatic ones - flexibility, mobility, balance and strength, in boys, and choreographic elements, in girls (Vieru, 1997; Readhead, 2011; Gaverdovskij, 2014).

According to the compositional requirements and the specificity of the apparatus (floor), women's artistic gymnastics uses different walkovers and somersaults belonging to different groups – forward, backward, sideways; the double somersault is a mandatory compositional requirement. Knowing the correlative connections between the biomechanical characteristics of double somersault and the performances achieved in floor event by junior female gymnasts and also the significance of these connections can contribute to a more efficient development of the modern didactic programs of learning (Potop, 2015).

2. Problem Statement

Artistic gymnastics has registered remarkable progress, demonstrating that it develops in compliance with the performance sports trends, but it also has its specific features (Arkaev & Suchilin, 2004, pp. 22-29). At the same time, it reveals a new level of development because the changes in the

Code of Points have entailed significant modifications in the exercise construction and execution and in the compositional requirements as well (FIG, 2017).

The complexity of the current gymnastics technique requires a new “technology” able to decipher the internal mechanisms of movement in order to know and use them for increasing performance. Modern trends originate from the biomechanics field, as a scientific branch dedicated to the discovery of these mechanisms (Crețu, 2004; Potop, Manole, Nistor & Andreyeva, 2015).

Biomechanics research in artistic gymnastics can be achieved both by biomechanical methods and those taken from other fields of knowledge (the pedagogical, mechanical, physiological, psychological, medical ones etc.), with the main goal to highlight the characteristics of movement (Brüggmann, 1994; Arkaev & Suchilin, 2004; Rosamond, 2006; Knudson, 2007; Gaverdovskij, 2014).

The learning of gymnastics technique reaches high levels of complexity and relies on “closed” motor skills (Manno, 1996). In these conditions, one tends to over-automation, overlearning, with a focus on details (Crețu, Bărbuceanu, & Simăn, 2004, p. 12).

In the search for new methods to improve sports training in women’s artistic gymnastics, there are many interdisciplinary studies about the improvement of the technical training system by using the computerized biomechanical video analysis of sports technique execution and the biomechanical recommendations for a correct execution. There have been developed technical preparation programs that contain accurate means selected according to kinematic and dynamic criteria (Knoll, 1996; Hraski, 2002; Crețu, Bărbuceanu, & Simăn, 2004; Potop, Jurat, & Bufta, 2017).

Current orientations in the biomechanical research specific to this sports branch, the floor, involve, in most exercises: jumps, simple or multiple rotations with intermediate support on the palms - walkovers and without intermediate support (from sole to sole) - somersaults (Crețu, Bărbuceanu, & Simăn, 2004).

3. Research Questions

In order to conduct our research, we have proposed the following questions:

Does the biomechanical analysis of double back somersault on floor, using the computerized video method of movement postural orientation and evaluation of sports technique, highlight the key elements and the synchronization of their spatial-temporal characteristics?

Does the parametric linear correlative analysis of the anthropometric and biomechanical indicators of the tucked and piked double back somersault and the performances achieved in floor events reveal different degrees of connection between indicators and their significance?

Does the non-parametric linear correlative analysis show different degrees of connection between the biomechanical characteristics, the results obtained in competition and the relationship of the analysed indicators of sports technique key elements used in double back somersault on floor?

4. Purpose of the Study

The aim of this paper is to highlight the degree of connection between the kinematic and dynamic characteristics of sports technique key elements used in double back somersault and the performances achieved by junior gymnasts in floor events.

5. Research Methods

This scientific approach is part of the formative pedagogical experiment performed at the end of the competitive year 2014. For this purpose, we used the following research methods: bibliographic study of the literature; pedagogical observation, which was used for monitoring the evolution of junior gymnasts in competition; computerized video method by means of "Pinnacle Studio" program for converting the video format to AVI and synchronizing the key elements of sports technique (Potop, 2015); "Physics ToolKit" program for analysing the kinematic and dynamic characteristics of double back somersault; method of movement postural orientation and evaluation of sports technique key elements with complex coordination of movement structure (Boloban, 2013, pp. 51-55); statistical-mathematical method (Thomas & Nelson, 1996) – KyPlot program for parametric (Pearson) and non-parametric (Spearman Rank Correlation) linear correlative analysis.

During this research, we analysed 12 double back somersaults (6 tucked double back somersaults, the gymnast M.A. executing one double back somersault with 360-degree turn, and 6 piked double back somersaults executed by 8 junior gymnasts in the all-around event at the National Championships of Romania, Bucharest 2014).

6. Findings

The computerized biomechanical video analysis was performed with the "Kinovea" program for measuring the angular characteristics of body segments and the "Physical ToolKit" program for processing the kinematic and dynamic characteristics of sports technique key elements in double back somersault on floor (Figure 01).

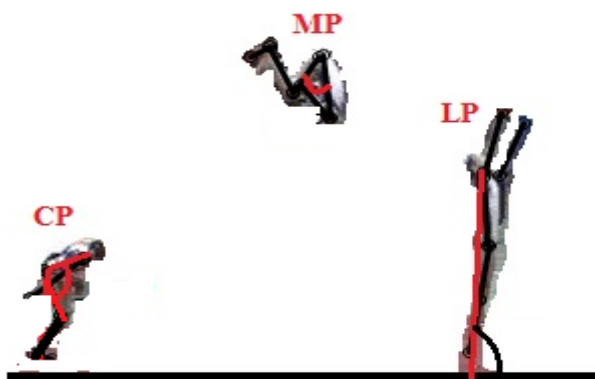


Figure 01. Key elements of sports technique in double back somersault

Note: preparatory phase of movement, launching posture (LP) - angle between the lower horizontal floor - shoulders and shoulders - flipping angle; basic phase of movement, multiplication of body posture (MP) - maximum flight height (MFH) of the general center of gravity (GCG) - somersault rotation, thigh-torso angle and final movement phase (FM) - concluding posture (CP) of the body - landing - thigh-torso angle

Table 01 shows the results and significance of the parametric linear correlation between the anthropometric indicators, inertia of rotation, range of motion of the body segments during the execution of double back somersault on floor and the results achieved in competition.

Table 01. Results of the parametric linear correlation between the anthropometric and biomechanical indicators of double back somersault on floor and the results achieved in competition

R, t	Result in competition	Height (m)	½ body height, arms up (m)	½ body weight (kg)	IR (kg•m ²)	RM / GCG (m)			
						Toes	Knee	Shoulders	Arms
TDS (n=6)	Difficulty (points)	.057 >0.05	-.019 >0.05	.248 >0.05	.108 >0.05	.552 >0.05	.898 <0.05	-.717 >0.05	-.925 <0.01
	Execution (points)	-.252 >.05	-.340 >0.05	.004 >0.05	-.175 >0.05	-.159 >0.05	.507 >0.05	-.285 >0.05	-.621 >0.05
	Final score (points)	-.167 >0.05	-.260 >0.05	.096 >0.05	-.088 >0.05	-.008 >0.05	.625 >0.05	-.361 >0.05	-.708 >0.05
PDS (n=6)	Difficulty (points)	-.536 >0.05	-.504 >0.05	-.284 >0.05	-.391 >0.05	-.502 >0.05	-	-.143 >0.05	-.797 >0.05
	Execution (points)	.125 >0.05	.052 >0.05	.217 >0.05	.148 >0.05	.260 >0.05	-	.762 >0.05	.508 >0.05
	Final score (points)	.034 >0.05	-.028 >0.05	.179 >0.05	.091 >0.05	.168 >0.05	-	.743 >0.05	.312 >0.05

Note: TDS - tucked double somersault, PDS - piked double somersault, R - coefficient of parametric linear correlation; t – significance of correlation; df = n-2; p<0.05, r = .811; p<0.01; r = .917; IR - inertia of rotation; IR = ½ kg • ½ m²; RM - range of motion; GCG - general center of gravity of the body

The results of the parametric linear correlative analysis highlight:

- TDS (n=6) shows strong connections between difficulty and arm range of motion at p<0.01, difficulty and knee range of motion at p<0.05 and moderate connections between difficulty and final score and the range of motion of toes, shoulders and arms;

- PDS (n=6) reveals moderate connections between: difficulty and anthropometric indicators and arm range of motion; execution and range of motion of shoulders and arms; final score and shoulder range of motion.

There is a poor and very poor correlation between the results in competition and the analysed anthropometric and biomechanical indicators.

Table 02 shows the results of the non-parametric correlation between the indicators of the biomechanical characteristics of sports technique used in double back somersault on floor and the results obtained in competition.

The non-parametric correlative analysis between the biomechanical characteristics, the results achieved in competition and the indicators of sports technique key elements of double back somersault on floor was made using the Spearman Rank Correlation test. Seven biomechanical indicators were selected to determine the relationship between the indicators of kinematic and dynamic characteristics, namely: trajectory of GCG (x, y), angular characteristics of segments in the launching posture (LP), angle between floor horizontal - toes and shoulders in MP and CP, angle between thigh and torso, angular velocity of toes, shoulders and arms and the resultant force of GCG displacement; also the results obtained in floor event (difficulty, execution and final score).

Table 02. Results of non-parametric correlation between the biomechanical characteristics, the indicators of sports technique used in double back somersault on floor and the results achieved in competition (n = 12)

No.	Indicators	Indicators									
		LP			MP; CP						
		8	9	10	11	12	13	14	15	16	17
LP	GCG, x (m)	-.428	.234	.095	-.517; -.497	-.308; -.504	-.046; -.354	.818; .671	.671; .231	.776; .615	-.277; -.091
	GCG, y (m)	-.381	-.293	-.333	.228; .291	.336; .501	-.246; -.102	-.441; -.193	-.172; -.329	-.406; -.059	.527; -.392
	Toes-shoulders (degrees)	-.213	-.113	-.160	- -	- -	-.288; -.184	.627; .874	.814; .188	.701; .641	-.357; -.085
	Toes (rad/s)	-.231	-.297	-.285	- -	- -	-.112; -.263	.531; .594	.713; .182	.559; .790	-.042; -.112
	Shoulders (rad/s)	-.289	.046	.014	- -	- -	.039; -.322	.727; .601	.594; .147	.720; .804	-.154; -.175
	Arms (rad/s)	-.161	.124	.081	- -	- -	.211; -.126	.811; .699	.559; .511	.832; .811	-.414; .308
	GCG (N)	.586	.152	.299	- -	- -	-.063; .084	.000; -.189	.035; -.392	-.035; -.378	-.586; -.252
	Difficulty (points)	-	.400	.630	.092; .081	.388; -.128	.479; .273	-.033; -.362	-.212; -.007	-.092; -.362	-.057; .004
	Execution (points)	-	-	.952	.166; .138	-.120; -.474	.519; -.009	.237; .057	-.163; .347	.106; -.241	-.119; .315
	Final score (points)	-	-	-	.197; .137	.028; -.461	.606; -.004	.183; -.102	-.225; .218	.053; -.250	-.113; .218
MP	GCG, x (m)	-	-	-	.923	.489	.154	-.825	-.392	-.636	-.084
	GCG, y (m)	-	-	-	.161	.469	-.112	-.413	-.615	-.378	-.741
	Thigh-torso (degrees)	-	-	-	-	-	.163	-.200	.428	.084	.456
	Toes (rad/s)	-	-	-	-	-	-.126	.622	.483	.601	.063
	Shoulders (rad/s)	-	-	-	-	-	-.196	.720	.182	.511	-.217
	Arms (rad/s)	-	-	-	-	-	-.038	.713	.489	.636	.126
	GCG (N)	-	-	-	-	-	-.070	-.218	-.063	-.165	-.049

Note: r - Spearman Rank Correlation; df = n-2, n = 10, p<0.05, r = .576; p<0.01, r = .707; LP - launching posture; MP - multiplication of body posture; CP - concluding (final) posture - landing

The results of the correlative analysis between the biomechanical characteristics of double back somersault on floor and the results obtained in competition highlight strong connections at p<0.05 in the basic movement phase, multiplication of body posture (MP) and the final score on floor, moderate connections between MP and execution, while the other indicators of the biomechanical characteristics show weak or even very weak connections.

Regarding the correlation between the results achieved in floor event, we note strong connections at p<0.01 between execution and final score, and at p<0.05, between difficulty and final score.

A multiple correlative analysis was made for highlighting the connections between the indicators of the biomechanical characteristics and the key elements of sports technique used in double somersault, namely the relationship between LP – MP, LP – CP and MP – CP (Table 02).

In this relationship, the launching posture (LP) in the preparatory movement phase, the multiplication of body posture (MP) in the basic movement and the concluding posture (CP) – landing in the final phase (concluding phase) show strong connections at p<0.01 between:

- trajectory of GCG (x) and angular velocity of toes in MP;

- angular characteristics and angular velocity of shoulders in MP and angular velocity of toes in CP;
- angular velocity of toes and shoulders and angular velocity of arms in CP;
- angular velocity of arms and angular velocity of toes and arms in MP and angular velocity of arms in CP.

Within the relationship of the basic movement phase, multiplication of body posture (MP) and the final phase, concluding posture (CP), there are strong connections at $p < 0.01$ between:

- Trajectory of GCG (x) in the flight phase and trajectory of GCG (x) in CP at landing.

The relationship of LP-MP and LP-CP shows strong connections at $p < 0.05$ between the key elements of sports technique of double back somersault, revealing mutual influences between the indicators of the biomechanical characteristics, excepting the trajectory of GCG (y), and the resultant force, which has poor connections, namely the force cannot influence the GCG trajectory in flight phase.

In the relationship MP and CP, there are strong connections at $p < 0.05$ between the trajectory of GCG (y) and the angular velocity of shoulders and the resultant force of GCG, which has influenced the correct execution of landing.

7. Conclusion

The use of movement postural orientation method for analysing the sports technique of double back somersault on floor highlighted the synchronisation of the sports technique key elements in terms of launching posture during the preparatory movement phase; in the basic movement phase, multiplication of body posture at the moment of GCG maximum height executed in tucked or pike position; in the final movement phase (conclusion), the concluding posture - landing.

The parametric linear correlative analysis was meant to show the degrees of connection between the anthropometric and biomechanical indicators of double back somersault on floor and the performance obtained in competition. The non-parametric correlative analysis revealed the degrees of connection between the biomechanical characteristics and the results achieved in competition and also the influence of studied indicators on the key elements of sports technique in double back somersault on floor.

The comparative correlative analysis (made by parametric and nonparametric statistical methods) between the biomechanical characteristics and the performances obtained in competition by junior gymnasts reveal different degrees of connection of the studied indicators and their consistent relationship with the kinematic and dynamic particularities of sports technique of double back somersault on floor, which confirms the hypothesis proposed in the paper.

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