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Analysis of the Influence of Sensorimotor Coordination Development on the Technical Execution of Balance Beam Dismounts

Vladimir POTOP^{1*}, Valeriu JURAT², Ion CARP³

Abstract

The purpose of this paper is to reveal the influence of sensorimotor coordination development on the technical execution of balance beam dismounts in the case of junior gymnasts aged 12 to 15 years. To achieve the purpose and objectives of the research, we used the following methods: review of specialized literature; pedagogical observation method; pedagogical experiment method; tests method; video computerized method of biomechanical analysis; method of movement postural orientation; statistical-mathematical method and graphical representation method. In this study we used 3 tests of assessment of sensorimotor coordination development: test 1 – stuck landing; test 2 – "Brink" test, static balance and test 3 – static-kinematic stability. The biomechanical analysis was made by means of Physics ToolKit Version 6.0 program, monitoring the key elements of sports technique used in the dismounts off balance beam. The study findings show the level of sensorimotor coordination development in terms of spatial-temporal orientation, vestibular coordination and balance, kinematic and dynamic analysis of sports technique key elements regarding body segments trajectories, angular speeds and force momentum during dismounts off balance beam. As for the correlation of sensorimotor coordination indicators with performance results on balance beam, there are significant differences which confirm the influence of the sensorimotor coordination on junior gymnasts' technical training on this apparatus. Also, the evaluation of sensorimotor coordination consistent with the biomechanical analysis of sports technique of dismounts off balance beam in the case of junior gymnasts aged 12 to 15 highlights their influence on the technical training and performances achieved in competitions.

Keywords: Balance beam; dismount; sensorimotor coordination; technique; performance.

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1. Introduction

Artistic gymnastics currently registered remarkable progresses, characterized by motor coordination, emotional balance, resistance to stress, focused attention, vestibular balance etc. Balance beam, the third event specific to women's artistic gymnastics, is characterized by both physical and mental balance. In conformity with the regulations, the exercise on balance beam must include a mount, the content with difficult elements belonging to different structural groups and a dismount [1], [21], [27]. The dismount is the most important moment of each routine because the last impression depends on it. In the table of difficult elements on balance beam included in the Code of Points [7], the dismount is the 6th group of elements and includes 7 types of dismounts, with different values of difficulty (A, B, C, D, E, F and G).

With regard to the forms of manifesting the coordination capacity (skill) in artistic gymnastics, a number of "senses" or psychomotor skills are included, namely [14]: sense of balance; sense of orientation in space; sense of coordination of the movements made by the mobile segments; sense of coordination of the large muscle groups; sense of decomposition and analysis of movements; sense of rhythm; sense of assessment of distance, direction, velocity, amplitude and degree of strain.

The coordinative capacity is largely dependent on the efficiency of the analyzers that influence directly the process of movement guidance and control. These analyzers cooperate and complement each other as follows [5],[15]: static-dynamic (vestibular) analyzer; kinesthetic analyzer; touch analyzer; sound analyzer; optical analyzer.

Biomechanics research in artistic gymnastics can be made both by methods of biomechanics and methods taken from other fields of knowledge (pedagogical, mechanical, physiological, psychological, medical field etc.) with the main target to point out the core features of the movement [1], [6], [13].

According to the current compositional requirements and the specific of the apparatus (balance beam), women's artistic gymnastics must contain culminating points created by connecting two or several acrobatic, gymnastics or mixed elements [27] As the dismount is not a compulsory technical requirement it must be consistent with the difficulty of the entire exercise and the specific demands of the contest [20].

The knowledge of the correlative connections between the sensorimotor coordination indicators, the biomechanical ones and the performances on balance beam achieved by junior female gymnasts of 12 - 15

years old and also the significance of these connections can contribute to the more efficient development of the modern didactical programs of learning.

2. Problem Statement

The coordinative skills of athletes are quite different and specific to each sports branch. However they can be distinguished according to the particularities of manifestation, criteria of evaluation and conditioning factors. In training and competition real practice, all coordinative abilities are not manifested separately but in a complex interaction [16]. In terms of sense of balance and body posture, the vestibular analyzer plays an important role [8], [23].

Thus, the coordinative abilities designate a complex of predominantly psycho-motor skills including the ability to learn fast new movements, to adapt quickly and efficiently to various conditions, specific to different types of activities, by reconfiguration of the motor background [10].

According to Blume (1981), quoted by Manno, the coordinative abilities are organized under the form of a system, taking into consideration the inter-conditioning of components and their purposes [11]. The manifestation forms of the coordinative abilities can be defined as follows [12]: general coordinative abilities, specific coordinative abilities and coordinative abilities under the conditions of other motor skills.

According to Berstein (1991), the optimal operation of the sensitive vestibular system has a great importance for achieving high results in different branches of sport [22], primarily in those sports in which the athlete must have a very good sensory-motor coordination. The increasing sports mastery and competitive programs difficulty require a specialized analysis to reveal the influence of different factors upon the vestibular analyzer and also the influence of the mechanical forces resulted from the inertial forces in linear and angular accelerations[2], [9].

In terms of physiology, the coordination capacity can be defined as a complex psycho-motor quality based on the correlation between the central nervous system and the skeletal muscles during the performance of a movement [5].

The regulation of body posture – aspiration of the body to functional order, to the updating and coordination of human body units in balance – is an effective solution to define the motor tasks [3].

The review of specialized literature certifies the importance of the research on gymnastics exercises technique and its learning, taking into

account the body postures and positions and the synchronized key elements of sport technique [19],[24].

The coordinative capacity is a psychomotricity component included in a complex aptitude with a very important role in the life of a human, therefore of a gymnast [14]. This capacity interferes with other aptitudes too, even with motor skills and abilities [25], [26].

Because coordination is a natural inherited capacity, the specific methods to develop it are quite few in comparison with other bio-motor capacities. During the coordination development stages, the coach must try to use exercises of progressive increasing complexity. The difficulty and complexity of a skill can be enhanced by using situations, different sports equipment and facilities [4].

3. Research Questions/Aims of the research

This paper aims to highlight the influence of sensorimotor coordination development on the technical execution of balance beam dismounts in the case of junior gymnasts aged 12 to 15 years.

Hypothesis of the paper. We believe that the assessment of sensorimotor coordination is consistent with the biomechanical analysis of sports technique of the balance beam dismounts executed by junior gymnasts of 12 – 15 years old. We shall show its influence on the technical training and the performances achieved in competition.

4. Research Methods

The following methods have been used to achieve the tasks of the research: theoretical analysis and generalization of specialty literature data; pedagogical observation; pedagogical experiment; method of tests (testing of sensorimotor coordination) [2]; video computerized method of biomechanical analysis, by the "Kinovea" program for analyzing the angular characteristics of sports technique key elements of the dismounts off balance beam and the "Physics ToolKit" program for analyzing the kinematic and dynamic characteristics of the dismounts; method of movement postural orientation [3], [21]; statistical-mathematical and graphical methods using the KyPlot programs.

A number of 3 tests for assessment of the sensorimotor coordination were used in this study [17], [18]:

1. Test 1 – “Briuk” test, static balance, test for maintaining body balance on tiptoe with eyes closed and arms along the body (holding at least 15-20 sec.).

2. Test 2 –static-kinematic stability – 5 forward rolls in 5 sec. with 10 in-place jumps with eyes closed, in the centre of the graduated circle (maximum deviation 35 cm).

3. Test 3 – stuck landing, in-depth salto from the higher bar (uneven bars), assessed by penalties for the execution mistakes 0.1 -1.0 points; 3 attempts were granted.

This scientific approach involved the organization of an experimental study, as part of a postdoctoral research, conducted from 2012 to 2014, with a group of 8 gymnasts of 12 to 15 years old, members of the Olympic Team of Izvorani in that period.

During the research we analyzed 6 dismounts (3 with back salto layout with 720° twist - BSL720°, 2 - BSL900° and 1 with double back salto piked - DSP) in 2012 and 8 dismounts (3 - BSL720°, 2 - BSL900°, 1- BSL1080°, 1- DSP and 1 – double back salto tucked - DST) in 2014.

5. Findings

Table 1. Results of sensorimotor coordination development of junior gymnasts aged 12 to 15, (n=8)

Statistics indicators	Test 1 (s)		Test 2 (cm)		Test 3 (points)	
	Initial	Final	Initial	Final	Initial	Final
\bar{X}	14.89	18.54	24.38	21.25	9.28	9.49
SD	1.94	2.38	3.29	1.91	0.14	0.06
t	4.223		3.216		4.822	
P	<0.01		<0.05		<0.01	

Table 1 shows the results of the sensorimotor development of junior female gymnasts of 12-15 years old in terms of static balance, static-kinematic stability and stuck landing.

In table 2 are presented the results of the angular characteristics of sports technique key elements used in the balance beam dismounts performed by junior female gymnasts aged 12 to 15 years concerning the preparatory movement – launching posture (LP), the basic movement – multiplication of body posture (MP) in the maximum height of GCG flight and the final movement phase – concluding posture (CP) – the landing.

Table 2. Results of the angular characteristics of sports technique key elements of the dismounts with twisting back salto layout executed by junior female gymnasts aged 12 to 15 years (2012, n=5; 2014, n=6)

Statistics indicators	LP (degrees)		MP (degrees)		CP (degrees)			
	toes – should		thigh-torso		thigh-torso		thigh-torso	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
	104.4	98.17	188.2	205.5	158.2	165.67	106.2	132.67
SD	2.07	3.97	17.22	6.77	5,27	5.16	24.09	5.57
t	3.151		2.278		2.302		2.634	
p	<0.05		<0.05		<0.05		<0.05	

Note: t-Test (Assuming Equal Variances) Unpaired Comparison for Means; LP – launching posture; MP – multiplication of body posture; CP – concluding posture (final) – landing.

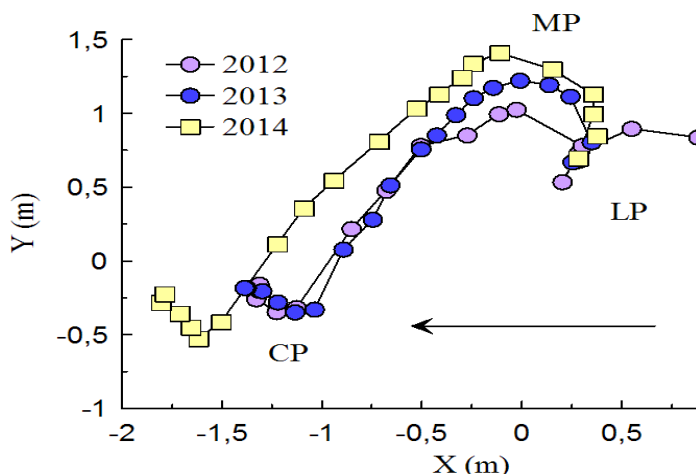
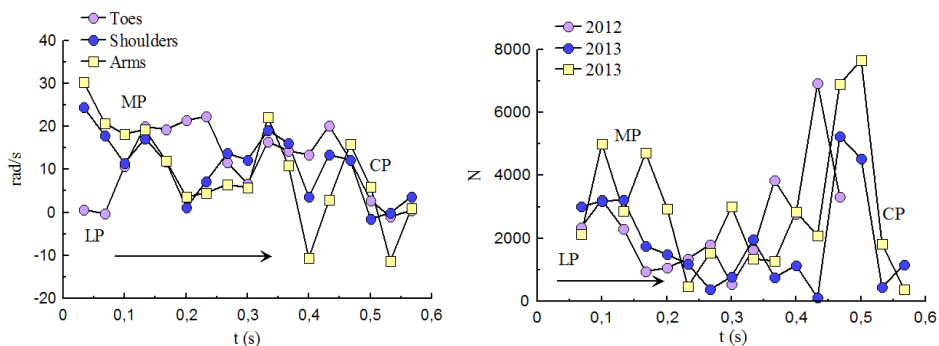


Fig. 1. Graph of GCG trajectory during execution of the back salto layout with 720 degrees twist dismount, gymnast B.A. (12-14 years old)

Figure 1 shows the graph of GCG trajectory of the back salto layout with 720 degrees twist (BSL720°) dismount executed by the gymnast B.A. (12-14 years old) during the Romanian National Championships of Women’s Artistic Gymnastics 2012-2014, in terms of dynamics of the key elements of sports technique.



a) Angular velocity

b) Resultant of GCG force

Fig. 2. Kinematic and dynamic characteristics of the back salto layout with 720 degrees twist dismount, gymnast B.A. (12-14 years old)

In table 3 are presented the results of linear correlation of the sensorimotor coordination, biomechanical indicators and performances achieved in the balance beam events.

Table 3. Results of the linear correlation between sensorimotor coordination indicators, biomechanical indicators and performances achieved in balance beam events by junior gymnasts aged 12 to 15 (n=8)

No.	Indicators*	SMC			Biomechanics indicators					Performances			
		1	2	3	4	5	6	7	8	9	10	11	12
1	Test 1, (sec)		-	.615	.117	-	-	-	-	-	-	-	-
2	Test 2, (cm)	-.288		-	-	.060	.074	.194	.402	.114	.153	.116	
3	Test 3, (points)	-	-.438		.039	-	-	-	-	-	-	-	
4	IR(kg·m ²)	-	-.499	-		.552	.717	.217	.067	-	.289	.292	.351
5	toes	-.540	-	-.443	-		.745	.774	.610	.491	.818	.556	.772
6	RM, should	-.109		-.510	-	-		.397	.426	-	.487	.457	.562
7	(m) arms	-.371		-.037	-	-	-		.358	.648	.939	.422	.710
8	KE, LP	-.275		-.498	-	-	-	-		.469	.228	.567	.552
9	(degrees) CP	-.472		-.227	-.302	-	-.007	-	-		.576	.282	.455
10	Diffic. (points)	-.548		-.191	-	-	-	-	-	-		.286	.623
11	Exec. (points)	-.107		-.367	-	-	-	-	-	-	-		.928
12	FS (points)	-.301		-.374	-	-	-	-	-	-	-	-	

Note: SMC –sensorimotor coordination, Perf.- performances, IR – inertia of rotation, RM – radius movement, should.- shoulders, KE – key elements, LP - launching posture, CP – concluding posture, Diffic. – Difficulty; Exec. – Execution; FS – final score; $df = N-2$, $p < 0.05$, $r = 0.707$; $p < 0.01$, $r = 0.834$.

6. Discussions

The assessment of the sensorimotor coordination development of junior female gymnasts aged 12 to 15 years was made using three tests for static balance, static-kinematic stability and stuck landing [17], [18]. The results of the comparative analysis reveal the following matters (table 1, \bar{x} ; \pm SD): in test 1 an average of 14.89; \pm 1.84 cm in initial testing and an increase of the balance holding duration by 3.65 sec in final testing with significant differences between averages at $p < 0.01$; in test 2 an average of 24.38; \pm 3.29 cm in initial testing and improvement of static-kinematic stability by 3.13 cm (diminution of deviation) in final testing with significant differences between averages at $p < 0.05$; in test 3 an average of 9.328 0.14 points in initial testing and an increase by 0.21 points of landing stability in final testing and significant differences at $p < 0.01$.

The results of the comparative analysis between the angular characteristics of sports technique key elements in the dismounts with twisting back salto layout executed by junior gymnasts aged 12-15 years highlight the following matters (table 2, $n=6$, \bar{x} ; \pm SD): the launching posture (LP) was measured from two angles: the toes-shoulders angle has an average of 104.4; 2.07 degrees in initial testing and an improvement of the posture by 6.23 degrees in final testing and significant differences at $p < 0.05$. The thigh-torso angle has an average of 188.2; 17.22 degrees in initial testing and an increase by 17.3 degrees in final testing and significant differences between tests at $p < 0.05$; the multiplication of body posture (MP) at maximum height of GCG flight (angle between thigh and torso) has an average of 158.2; 5.27 degrees in initial testing and an improvement of the posture (increase of the angle) by 7.47 degrees in final testing and significant differences between the average values at $p < 0.05$; in concluding posture (CP) – landing (\bar{x} ; \pm SD) the thigh-torso angle has an average of 106.2; 24.09 degrees in initial testing and an improvement of posture angle by 26.47 degrees in final testing and significant differences of the average values between tests at $p < 0.05$.

The results of the comparative analysis of the individual biomechanical indicators of the 720 degrees twisting back salto layout dismount (BSL720°) executed by the gymnast named B.A. (12-14 years old) highlight (fig. 1): the increase of the height of GCG flight from 1.026 m by 0.385 m in final testing (1.411 m); at the same time the dismount length increased from 1.329 m by 0.383 m in final testing, having the end of the beam as a point of reference.

Regarding the kinematic characteristics of the BSL720° dismount executed by the gymnast B.A. (12-14 years old), in terms of angular velocity

of body segments rotation around GCG, one can observe the following (fig. 2a): at launching posture (LP) there is a higher value of arms angular velocity, namely 20.718 rad/s related to shoulders and toes and a smaller value compared to year 2012 (22.88 rad/s), ensuring the optimum angle of flyaway off balance beam; during multiplication of body posture (MP) at maximum height of GCG flight there is a higher value of the angular velocity of 19.322 rad/s at toes level and close values of 11.9 and 11.972 rad/s in shoulders and arms, ensuring the body rotation around hip axis; in the concluding posture (CP) – landing, we notice a higher value for shoulders - namely 3.702 rad/s, 0.956 rad/s for arms and 0.504 rad/s for toes, ensuring the completion of landing.

As for the values of the resultant of the comparative force of GCG movement during the dismount by BSL720° performed by the gymnast B.A. (12-14 years), these ones reveal the following (fig. 2b): in LP a value of 2340 N in initial testing (2012) and a diminution of 2140 N in final testing; in MP – 2310 N in initial testing and an increase of 2410 N in final testing; in CP – 3320 N in initial testing and a decrease of 2947 N in final testing.

All these changes of the spatial-temporal characteristics, angular velocity and force resultant within the phasic description of sports technique of the BSL720° dismount helped to improve the key elements by optimizing the flyaway angle, increasing the height of GCG flight, increasing the length of the stuck landing, while ensuring a correct execution in accordance with the technical requirements of the International Code of Points.

These significant differences reveal the improvement of sports technique key elements of the dismounts with (720-1080 degrees) twisting back salto layout due to the implementation of the learning macro-methods during the training of junior gymnasts [20], [21].

The results of the linear correlative analysis between the sensorimotor indicators, the biomechanical indicators and the performances obtained in the balance beam events by the junior gymnasts of 12-15 years old reveal strong connections at $p < 0.01$ between the radius of movement (RM) of arms and the final score, between the execution score and the final score; at $p < 0.05$ between the RM of toes and the RM of shoulders, arms, difficulty and final score. The other indicators reveal moderate and poor connections between them.

7. Conclusions

The results of the study emphasize the improvement of the sensorimotor coordination by increasing the duration of static balance

maintaining, diminution of deviation of the static-kinematic stability and improvement of the stuck landing.

The video-computerized biomechanical analysis consistent with the method of movement postural orientation highlights the improvement of the sports technique key elements of balance beam dismounts executed by junior gymnasts of 12-15 years old based on the indicators of the kinematic and dynamic characteristics and the performances achieved in competition.

The results of the linear correlative analysis point out strong connections between the indicators of the sensorimotor coordination and the performances obtained in the balance beam events and moderate connections between some biomechanical indicators.

Also, the assessment of sensorimotor coordination consistent with the biomechanical analysis of sports technique used in balance beam dismounts in the case of junior gymnasts aged 12 to 15 highlights its influence on the technical training and performances achieved in competitions.

8. Acknowledgment

This case study is an advanced stage of the pedagogical experiment of the post-doctoral thesis; it is included in the research plan of National University of Physical Education and Sport of Ukraine, with the subject matters: 2.11 (Dynamic static stability as a basis for technical training of those involved in sports gymnastics), 2.32 (Technical training of skilled athlete based on competitive exercises technique rationalization) and in the plan of research for 2016-2017 of the Faculty of Physical Education and Sport, Ecological University of Bucharest.

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I hereby declare under my own responsibility that the subjects participating in the research have been informed of the voluntary nature of participation in the research, of the understanding of the information received and of the understanding that withdrawal can be done at any time, without any negative consequences on the participant.

The research respected the ethical standards of the research, the participants / the next of kin of the participants gave their consent to take part in the research.

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