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INFLUENCE OF SENSORY-MOTOR COORDINATION ON THE TECHNICAL TRAINING IN WOMEN'S ARTISTIC GYMNASTICS

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Abstract: *Artistic gymnastics practicing requires particular aptitudes from those who wish to achieve special performances. This paper aims to highlight the influence of sensory-motor coordination on the technical training in women's artistic gymnastics. With this aim in view we have considered that the assessment of sensory-motor coordination, consistent with the biomechanical analysis of the key elements of sports technique, would highlight their influence on the technical training and on the performances achieved in competition. The study was conducted throughout the period November – December 2012 on a group of 9 junior female gymnasts 12 to 14 years old, members of the Olympic team of juniors of Deva. The work intends an ascertaining study of the training level of the junior gymnasts who are included in a research that will be carried out during the post doctoral studies.*
The results of the study highlight the development of sensory-motor coordination in terms of spatial-temporal coordination, balance and vestibular coordination; kinematic and dynamic analysis of the key elements of sports technique regarding the trajectories of body segments, the angular speeds and the momentum of force in the backward giant with handstand 360º twist on uneven bars; there are also shown the results achieved in competition as for the score D, E and final score on apparatus.

Key words: *biomechanical analysis, sensory-motor coordination, gymnastics, technical training, performance.*

1. Introduction

Artistic gymnastics develops in accordance with the trends of performance sport, but it has its specific features too, 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) [1].

Due to its aesthetic and spectacular valences, artistic gymnastics require special skills from those seeking high performance. These skills are [10], [12]:

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coordinative capacity (skill), velocity, force, joint mobility, muscle flexibility and strength.

In Berstein's opinion (1991), an optimum operation of the sensitive vestibular system has a great importance for achieving high sports results in various branches of sport, primarily in those sports where the athlete must have a high level of sensory-motor coordination. The increase of sports mastery, the growth of competitive programs difficulty require specialists' analysis meant to highlight the influence of different factors on the vestibular analyzer, and in the same time the influence of the mechanical forces arising as a result of the inertial forces in linear and angular accelerations [3].

From physiological point of view, 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 while performing a movement [5].

Regarding the forms of manifestation of the coordinative capacity (skill) in artistic gymnastics, this one includes a series of ”senses” called psychomotor skills, namely [10]: sense of balance; sense of orientation in space; sense of coordination of movements of various segments involved in motion; sense of coordination of large muscle groups activity; 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 movement guidance and control process. These analyzers cooperate and complement each other, namely [12], [5]: *static-dynamic* (vestibular) *analyzer*; *kinesthetic analyzer*; *touch analyzer; sound analyzer; optical analyzer*.

Because coordination is a natural capacity, inherited, there are not many specific methods for its development compared to other bio-motor capacities. During the phases of coordination development, the coach must seek to use exercises of progressively increasing complexity. The difficulty and complexity of a skill can be increased by using situations, various sports equipment and facilities [4].

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 [8], [9]: *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. [9].

Mistakes may occur throughout the learning or improvement of gymnastics movements. In these cases, things can not be allowed to continue in this way [15]. 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 [1].

Several criteria can be used for splitting gymnastic elements into parts, such as pedagogical, psychological, physiological, biomechanical criteria, 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* [14].

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 analysis of the data obtained [6], [11].

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 [7].

Three systems of coordination are used in the biomechanical analysis. One of them is the fixed or inertial coordination, which is usually related to gymnastics apparatus, while the other two – mobile (non-inertial) are related to athlete's body. The analysis of technique highlights the biomechanical characteristics and motion parameters. The biomechanical characteristics are divided into kinematic ones (spatial, temporal and spatial-temporal) and dynamic ones (strength and energy) [1].

2. The purpose of the paper

The purpose of this paper is to highlight the influence of sensory-motor coordination on the technical training in women's artistic gymnastics.

3. The hypothesis

We believe that the assessment of sensory-motor coordination, consistent with the biomechanical analysis of the key elements of sports technique, will highlight their influence on the technical training and on the performances achieved in competition.

4. Material and methods

The study was conducted throughout the period November – December 2012 on a group of 9 junior female gymnasts 12 to 14 years old, members of the Olympic team of juniors of Deva. We used for this research the bibliographic study method; pedagogical observation method; pedagogical experiment method; tests method; computerized video method for biomechanical analysis; statistical-mathematical method and graphical representation method.

The tasks of the pedagogical experiment are the following ones: assessment of the level of sensory-motor coordination development; kinematic and dynamic analysis of technical training basic elements and performances achieved in competition by junior female gymnasts of 12 to 14 years old. 3 tests were used during the study, meant to assess the sensory-motor coordination [2], [3]:

1. Test 1–standstill landing, jump in depth from the high bar (uneven bars), closed eyes landing (assessment by penalties applied for execution errors 0.1 - 1.0 pts.), 3 attempts were given;
2. Test 2–"Briuk" test, tiptoes closed eyes body balance maintaining (for about 15-20 sec. at least)
3. Test 3–static-kinematic stability–5 forward rolls in 5 sec. with 10 jumps in place, closed eyes in the center of the graduated circle (deviation of max. 35 cm).

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), in basic stage–*multiplication of position* of the body (MP) and in final stage–*final position* (FP). [2], [13].

5. Results

Results of sensory-motor coordination Table 1

Subjects	**Weight (kg)**	**Height (cm)**	**Arms up height**	**Test 1**	**Test 2**	**Test 3**
				Score	**Sec.**	**Cm.**
1	36.6	149	190	9.57	0.11	23.3
2	40.4	152	190	9.57	0.15	35
3	38.5	153	195	9.37	0.13	20
4	33.1	144	180	9.53	0.19	16.7
5	36.9	144	84	9.53	0.29	13.3
6	40.4	154	192	9.6	0.16	27.7
7	32.1	138	177	9.7	0.14	20
8	32.4	145	185	9.3	0.16	30
9	31.4	140	180	9.5	0.17	31.7
IS						
Mean	**35.76**	**146.56**	**174.78**	**9.52**	**0.17**	**24.19**
SEM	1.19	1.92	11.53	0.04	0.02	2.44
SD	3.59	5.75	34.59	0.12	0.05	7.33
Cv%	10.05	3.92	19.79	1.26	31.03	30.31

Results achieved in competition Table 2

Subjects	**Vaults**			**Uneven bars**		
	Score D	**Score E**	**FS**	**Score D**	**Score E**	**FS**
1	4.400	9.100	13.500	3.700	7.200	10.900
2	5.000	8.800	13.800	5.000	8.450	13.450
3	4.000	9.050	13.050	5.100	8.525	13.625
4	4.400	8.775	13.175	4.800	6.775	11.575
5	4.400	9.000	13.400	4.900	7.050	11.950
6	5.000	9.100	14.100	5.100	8.550	13.650
7	4.400	8.800	13.200	5.300	8.900	14.200
8	4.000	8.650	12.650	4.000	5.250	9.250
9	4.600	8.850	13.450	3.600	8.575	12.175
IS						
Mean	**4.47**	**8.90**	**13.37**	**4.61**	**7.69**	**12.31**
SEM	0.12	0.05	0.14	0.22	0.40	0.53
SD	0.36	0.16	0.42	0.66	1.21	1.59
Cv%	8.07	1.83	3.16	14.23	15.71	12.98

Legend: Score D- difficulty of exercise; Score E – execution; FS – final score

Continuation- results achieved in competition Table 3

Subjects	Beam			Floor		
	Score D	**Score E**	**FS**	**Score D**	**Score E**	**FS**
1	5.300	8.275	13.575	4.900	9.125	14.025
2	5.600	8.525	14.125	5.300	7.450	12.750
3	5.500	8.700	14.200	5.300	8.675	13.975
4	4.800	8.700	13.500	5.100	8.200	13.300
5	5.200	8.600	13.800	4.800	8.550	13.350
6	5.500	7.625	13.125	5.300	8.825	14.125
7	5.800	8.050	13.850	5.100	8.750	13.850
8	5.000	6.750	11.750	4.800	7.975	12.775
9	4.800	8.400	13.200	5.200	8.825	14.025
IS						
Mean	**5.28**	**8.18**	**13.46**	**5.09**	**8.49**	**13.58**
SEM	0.12	0.21	0.25	0.07	0.17	0.18
SD	0.36	0.64	0.74	0.21	0.52	0.55
Cv%	6.75	7.81	5.49	4.10	6.12	4.03

Legend: Score D– difficulty of exercise; Score E – execution; FS – final score

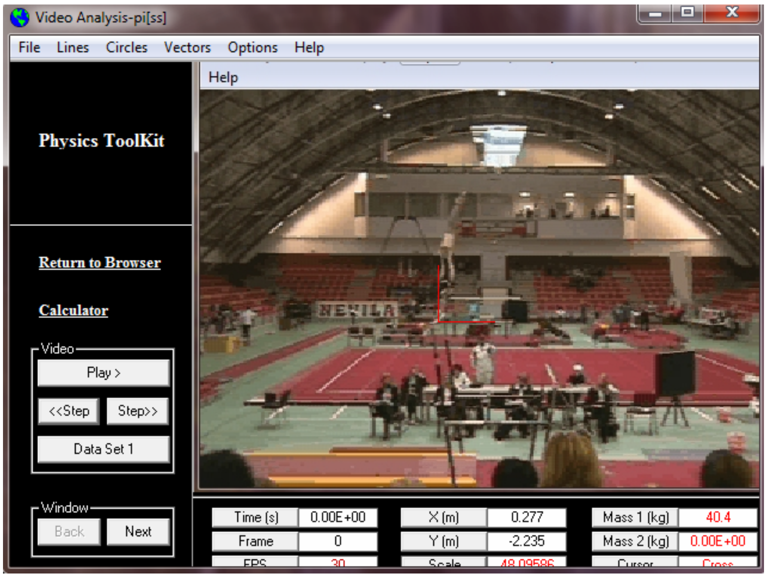

Fig.1. *Back giant with 360° twist in handstand (S.Ş.)*

Biomechanical indicators: Weight – 40.4 kg; Height in handstand 1.90m; inertia of rotation 145.844kgm^2; rotation ray CGG (hip) – 1.037m; rotation ray Vf.P. (toes)-1.841m; rotation ray A.U. (shoulder joint)-0.498m (fig.1).

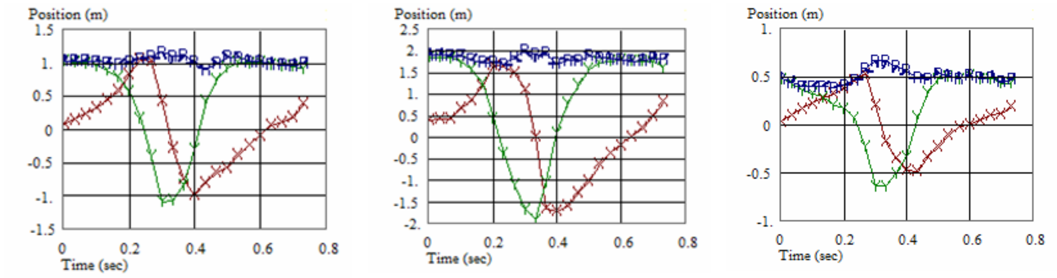

Fig. 2. *Position of body segments in back giant with 360º twist in handstand*

Specific biomechanical indicators of rotational movement Table 4

Time (sec)	**Key elements**	**C.G.G.**			**Vf.P**			**A.U.**		
		theta (rad)	**omega (rad/s)**	**torque (Nm)**	**theta (rad)**	**omega (rad/s)**	**torque (Nm)**	**theta (rad)**	**omega (rad/s)**	**torque (Nm)**
0.00	S.P - Handstand	1.49			1.35			1.49		
0.033		1.42	-2.33		1.34	-0.17		1.34	-5.65	
0.067	MP	1.33	-2.66	-2450	1.34	-2.09	-8620	1.13	-5.52	2090
0.1		1.24	-3.44	-4480	1.21	-4.07	-8760	0.97	-4.71	-1440
0.133		1.11	-4.69	-9630	1.07	-6.05	-18200	0.82	-6.17	-2620
0.167		0.93	-7.79	15500	0.81	-12.29	21200	0.56	-5.89	-294.907
0.2		0.59	-11.69	14900	0.26	-15.63	2850	0.43	-6.31	-14600
0.233	Horizontal moment	0.16	-14.53	19500	-0.23	-13.58	9260	0.15	-12.48	-33100
0.267		-0.36	-20.54	16700	0.63	11.44	1050	-0.39	-21.28	-20600
0.3		-1.19	-22.08	8280	0.98	-14.05	28400	-1.26	-21.78	16300
0.333	Low vertical moment	-1.82	-16.79	14400	-1.56	-24.28	24200	-1.84	-13.9	24900
0.367		-2.30	-15.58	7700	-2.58	-25.01	19100	-2.17	-10.51	-7580
0.4		-2.85	-20.27	4450	-3.21	-15.62	32000	-2.53	-17.33	-24500
0.433	Start of 180º twist	-3.64	-17.59	27200	-3.61	-10.52	16800	-3.32	-21.58	6170
0.467	MP	-4.01	-7.95	27400	-3.91	-8.00	7720	-3.95	-14.54	29100
0.5		-4.16	-5.18	6570	-4.14	-7.03	5330	-4.28	-8.42	18800
0.533		-4.36	-4.97	2340	-4.37	-5.59	7590	-4.51	-6.05	11800
0.567		-4.49	-4.12	1260	-4.51	-3.59	4970	-4.68	-3.09	8590
0.6	End of 180º twist	-4.63	-4.40	2130	-4.61	-3.34	203.95	-4.71	-2.16	-236.889
0.633		-4.78	-3.16	5460	-4.73	-3.49	-1540	4.82	-3.19	-798.109
0.667		-4.84	-1.93	2550	-4.84	-4.04	-3870	-4.92	-2.52	257.134
0.7	F. P.-End of 360º twist	-4.91	-4.32		-4.99	-5.25		-4.99	-3.08	
0.733		-5.12			-5.18			-5.13		

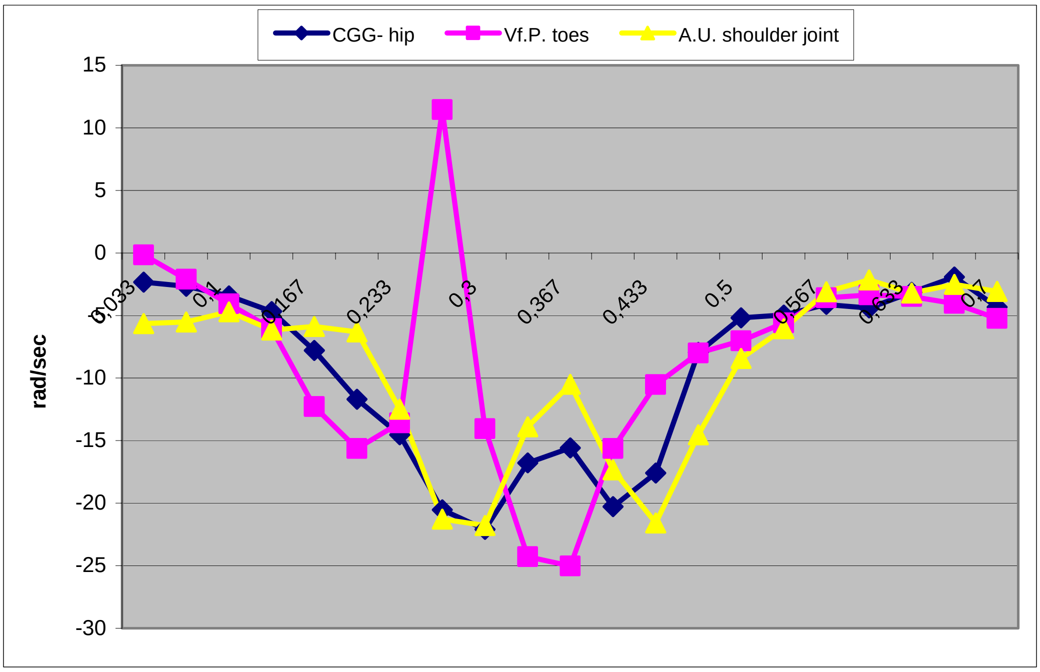

Chart no. 1. *Specific biomechanical indicators of rotational movement (S.Ş.)*

In chart no. 1 are shown the values of body segments angular speed during the execution of back giant with 360 º twists in handstand.

Table 5

Correlation of sensory-motor coordination indicators and the technical execution on apparatus

t, P	Vaults	Uneven bars	Beam	Floor
Test 1	10.34 < 0.001	4.78 < 0.01	6.57 <0.001	6.17 <0.001
Test 2	-151.22 <0.001	-18.45 <0.001	-38.12 <0.001	-47.12 <0.001
Test 3	6.21 <0.001	6.81< 0.001	6.31 <0.001	6.25 <0.001

6. Discussions

The research in this work has an ascertaining character within the subject matter of the post doctoral studies, which will focus on the macro-methods of gymnastics exercises learning in the stage of basic specialization in women's artistic gymnastics.

Only 9 junior female gymnasts, aged 12 to 14, were selected for this research; they are members of the Olympic team of Deva, participants in National Masters Oneşti, 16-18.XI.2012, having an average weight of 35.76kg, height: 146.56cm and 174.78cm in handstand (table no. 1)

As for the assessment of sensory-motor coordination of junior female gymnasts, three tests were used in this study, focusing on the spatial-temporal orientation, vestibular balance and coordination. The results of the tested indicators highlight an average of 9.52 points at the test no. 1, showing a good landing, with small instability mistakes; in test no. 2, called ”Briuk”, requiring to keep tiptoes position, closed eyes, the average is 0.17 seconds, which shows the initial level of balance sense; test no. 3, regarding the vestibular coordination, has an average of 24.19 cm of the deviations of the vertical jumps, closed eyes, in the center of the graduated circle (table no. 1).

Concerning the results achieved in competitions for handspring vaults, the average of D score(vault difficulty) is 4.47 points, the average of E score (technical execution) is 8.90 points, and the average of the final score is 13.37 points; on uneven bars, the average of D score (difficulty of exercise) is 4.61 points, the average of E score (technical execution) is 7.69 points and the final score average is 12.31 points (table no. 2); on beam, the average of D score (difficulty of exercise) is 5.28 points, the average of E score (technical execution) is 8.18 points and the final score average is 13.46 points; on floor, the average of D score (exercise difficulty) is 5.09 points, the average of E score (technical execution) is 8.49 points while the final score average is 13.58 points (table no. 3).

In terms of bio-mechanical analysis of key elements of sports technique, we have selected for example the back giant with 360º twist in handstand on uneven bars, basic element and specific requirement for this apparatus, executed by the national champion on this apparatus within the competition studied.

The biomechanical indicators of body segments trajectories during the studied movement are listed in figure no. 2 and table no. 4, highlighting the start position (SP) from handstand, when the highest angular speed is -5.65 rad/sec in shoulder joint (AU); the multiplication of body position (MP) is formed of the descending phase of going down from handstand position, emphasizing the horizontal moment at 0.233 sec., breaking under the lower bar at 0.267 sec, the value of the angular speed is -14.53 rad/sec in CGG; at the moment of the low vertical at 0.333 sec, the value of the angular speed is -24.28 rad/sec at toes.; then there is the ascending phase towards handstand position where the angular speed is -21.58 rad/sec. at 0.433 sec., while when the twist begins, in the same time with the entry into final position (FP) at 0.7 sec and the end of 360º twist in handstand, the angular speed is -5.25 rad/sec. at toes. Regarding the correlation of sensory-motor coordination indices with the scores for technical execution on apparatus, there are significant differences at $P<0.01$ and $P<0.001$, which confirms the influence of sensory-motor coordination on the technical training in women's artistic gymnastics (table no. 5).

5. Conclusion

The results of the study highlight the development of sensory-motor coordination in terms of spatial-temporal coordination, balance and vestibular coordination; kinematic and dynamic analysis of key elements of sports technique regarding the trajectories of body segments, the angular speeds and the momentum of force in the backward giant with handstand 360º twist on uneven bars; there are also shown the results achieved in competition as for the score D, E and final score on apparatus.

The assessment of sensory-motor coordination in compliance with the biomechanical analysis of the key elements of sports technique shows their influence on the technical training and on the performances achieved in competition.

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