Journal of Physical Education and Sport ® (JPES), 18 Supplement issue 5, Art 330, pp.2186 - 2192, 2018
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Analysis of the Specific Physical Training Influence on the Technical Execution of Double Salto Backward on the Floor

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Published online: November 30, 2018
(Accepted for publication November 20, 2018)
DOI:10.7752/jpes.2018.s5330

Abstract:
Purpose. This paper intends to show the influence of the specific physical training on the biomechanical characteristics of the double salto backward on the floor executed by the 14 to 17 years old female gymnasts. *Methods.* A number of 8 female gymnasts aged 14 to 17 years, members of the Olympic gymnastics team of Romania in 2014, finalists in the floor event of the Romanian Artistic Gymnastics National Championships, Bucharest, 2014, participated in this study. For the assessment of the specific physical training there were used 7 test events measuring the development of the following motor skills: strength-speed; force and specific endurance. There were also analyzed (by means of Kinovea and Physics ToolKit programs) 12 double saltos backward meant to highlight the kinematic and dynamic characteristics on the floor. *Results.* The results of Pearson's linear parametric correlative analysis reveal strong connections between the inertia of rotation and Test 1 at $p<0.01$ and Test 6 at $p<0.01$ and moderate connections between the indicators of movement radius of toes with Tests 6 and 7, between RM, shoulders with Tests 1 and 6; strong connections between the multiplication of body posture (MP) at $p<0.05$, moderate connections between the launching posture and Test 5; between MP and Test 7; strong connections between the indicators of the dynamic characteristics of force resultant within MP, GCG (F, N) and Test 1 (cm) at $p<0.05$, Test 2 at $p<0.05$, Test 3 at $p<0.05$, Test 5 at $p<0.05$ and moderate connections between the indicators of the launching posture (LP, GCG, Ym), between multiplication of posture (MP, GCG, Ym) and Test 2 (cm), between MP, GCG, F, N and Test 4 (no. of reps); the connections between the other indicators are weak or even inexistent. *Conclusions.* The correlative linear analysis of the specific physical training indicators and the biomechanical characteristics of the double salto backward on the floor executed by the female gymnasts of 14 to 17 years old highlighted the level of connection between the studied indicators and their influence on the technical execution.
Key Words: gymnastics, biomechanics, motor skills, correlation, performance

Introduction

Artistic gymnastics has lately experienced an unprecedented development, in terms of increase of sports mastery and improvement of training components as well. As an aesthetic sport, artistic gymnastics has special body movements characterized by good technique and beautiful shape, executed with easiness, amplitude and expressivity (Arkaev, & Suchilin, 2004; Filipenco & Buftea, 2014; Potop, 2015).

The big number of events, with different structures and requirements, determines the specific features of the movements on apparatus. From a biomechanical point of view, artistic gymnastics includes a large variety of movements which can be used in a large range of connections and combinations. Each and every apparatus has particular requirements of composition, technique and quality of execution (Grigore, 2001; Potop, 2014).

Like in other sports branches, the achievement of high performances depends on the motor possibilities which, in their turn, are strictly related to the level of physical (motor) skills development. The motor skills specific to gymnastics, listed in the order of their importance for the contents of the competitive effort, are the following ones: muscular strength – in various forms of manifestation, mobility and flexibility, specific endurance, skillfulness under the form of high coordination and speed under the form of response time and segmentary execution (Vieru, 1997).

Thanks to its rich and extremely diverse content, the floor is the longest event of great dynamisms and spectacularity. A women's artistic competitive floor routine will include a variety of linked tumbles, leaps and jumps joined together with choreographed dance movements. The double salto backward includes two full rotations in one take-off and it can be performed in tucked, piked or even stretched body position (Gaverdovskij, 2014; Readhead, 2011; Prassas, Kwon, & Sands, 2006; Sands, Caine, & Borms, 2003).

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Numerous scientific studies and research deal with the clear understanding and classification of gymnastics movements in terms of biomechanics (Cre□u, Simăn, & Bărbuceanu, 2004).
Purpose of the paper: to highlight the influence of the specific physical training on the biomechanical characteristics of the double salto backward on the floor executed by the female gymnasts aged 15 to 17 years.
Hypothesis of the paper. We believe that the correlative linear analysis of the specific physical training indicators and the biomechanical characteristics of the double salto backward on the floor performed by the gymnasts aged 14 to 17 years will show the level of connection between the studied indicators and their influence upon the technical execution.

Material & methods
Participants: Eight female gymnasts aged 14 to 17 years, members of the Olympic gymnastics team of Romania in 2014*,* finalists in the floor event of the Romanian Artistic Gymnastics National Championships, Bucharest, 2014, took part in this study.
Procedure

For the assessment of the physical training there were used 7 test events regarding the development of the motor skills strength – speed: test 1 – standing long jump (2 attempts, cm), test 2 – standing high jump (2 attempts, cm) and test 3 – rope climb with no leg support (seconds); strength: Test 4 – suspended on a fixed ladder, raising the legs up for 30 seconds (no. of reps), test 5 – prone trunk extension for 30 sec. (no. of reps), test 6 – jump to handstand on the beam (2 attempts, no. of reps) and specific endurance: test 7 – handstand hold on the beam (2 attempts, seconds).

A number of 12 double saltos backward (5 double saltos tucked, 1 double salto backward tucked with 1/1 twist and 5 double salto backward piked) executed by the 8 gymnasts-subjects of the study were analyzed in terms of biomechanics in order to show the kinematic and dynamic characteristics.
Data collection and statistical analysis
The biomechanical study of the acrobatic elements on the floor(namely the double salto backward) entailed the analysis of the indicators as follows: 1) biomechanical indicators: inertia of rotation (IR (kg·m^2), radius of movement of segments - toes, shoulders and arms (RM, m); 2) angular characteristics of the key elements of double salto technique: phase of preparatory movement - launching posture (LP)- angle between hip - torso, phase of basic movement – multiplication of body posture at the maximum height of the flight GCG (MP) – angle between hip - torso and the phase of final movement – concluding posture – landing (CP) – angle between hip - torso; spatial characteristics of the trajectory of the general centre of gravity (GCG, Xm, Ym during the phasic structure of the salto (LP, MP and CP); kinematic characteristics concerning the angular velocity of body segments (rad/s) – toes, shoulders and arms within the key elements of salto technique (LP, MP and CP); dynamic characteristics in terms of force resultant of GCG (F, N) – key elements of LP, MP and CP; performance on the floor (points): difficulty, execution and final score.
The indicators of the specific physical training are given by the 7 test events monitoring the development of the motor skills: strength –speed, strength – specific resistance.

Pearson's parametric linear correlation test, calculated by means of KyPlot program (Colton, 1974; Thomas & Nelson, 1996) was used for highlighting the connection level of the specific physical training indicators, the biomechanical characteristics of the double salto backward and the performances obtained in the floor event.

Results
Table 1 reveals the connection level of the indicators of specific physical training with the inertia of rotation and the radius of movement of body segments during the execution of double salto backward by the gymnasts of 14 - 17 years old.

Table 1. Correlation of specific physical training indicators with the inertia of rotation and the radius of movement of body segments (n=12)

Item	Biomechanical indicators		Strength - Speed			Strength			Specific Endur.
			Test 1 (cm)	Test 2 (cm)	Test 3 (sec)	Test 4 (rep no)	Test 5 (rep no)	Test 6 (rep no)	Test 7 (sec)
1	IR (kg·m^2)		**.767	.220	-.041	-.469	-.302	**.728	.355
2	RM, (m)	toes	.241	-.393	.317	-.273	-.293	.564	.544
3		should	.552	.209	-.095	-.296	-.175	.501	.158
4		arms	.090	-.147	.381	-.354	-.156	.242	.088

Note: IR – inertia of rotation, RM – radius of movement, should.- shoulders; df=10; **p-0.01, r=707
The results of Pearson's linear correlation show strong connections between the inertia of rotation and Test 1 where r=.767 at p<0.01 and Test 6 where r=.728 at p<0.01 and moderate connections between the indicators of

the radius of movement of toes with Tests 6 and 7, between RM, shoulders with Tests 1 and 6 while the connections between the other indicators are poor or even inexistent.

In table 2 is highlighted the connection level of the specific physical training indicators and the angular characteristics of the key elements of the double salto backward technique in the case of the female gymnasts aged 14 to 17 years regarding the phase of preparatory movement – launching posture, the phase of basic movement– multiplication of body posture at the maximum height of GCG flight and the phase of final movement – concluding posture – landing.

Table 2. Correlation of specific physical training indicators with the angular characteristics of the key elements of the technique used in the double salto backward (n= 12)

Item	Biomechanic indicators	Strength - Speed			Strength			Specific Endur.
		Test 1 (cm)	Test 2 (cm)	Test 3 (sec)	Test 4 (rep no)	Test 5 (rep no)	Test 6 (rep no)	Test 7 (sec)
1	LP, degrees	-.002	-.272	.329	.035	-.534	.326	.077
2	MP, degr	-.088	-.031	-.197	*.577	.062	-.444	-.501
3	CP, degr	-.021	-.080	-.322	.438	.112	.031	-.168

Note: LP – launching posture; MP – multiplication of body posture; CP – concluding posture (final) – landing .df=10; *p-0.05, r=576

The results of Pearson's linear correlation reveal strong connections between the multiplication of body posture (MP), regarding the angle between hip and torso at the maximum height of GCG in the basic phase, r=.577 at $p<0.05$, moderate connections between the launching posture – hip-torso angle and Test 5; between MP and Test 7; the connections between the other indicators are poor or even non-existent.

Table 3 highlights the level of connections between the indicators of specific physical training and the spatial characteristics of the trajectory of the general centre of gravity (GCG, Xm, Ym), the kinematic characteristics regarding the angular velocity of body segments (rad/s) toes, shoulders and arms and the dynamic characteristics regarding the resultant of force of GCG (F, N) in the phasic structure of the key elements of the technique of the double salto backward executed by the gymnasts who participated in this study.

Table 3. Correlation of specific physical training indicators with the spatial, kinematic and dynamic characteristics of the key elements of double salto backward (n= 12)

Item	Biomechanical indicators			Strength - Speed			Strength			Specific Endur.
				Test 1 (cm)	Test 2 (cm)	Test 3 (sec)	Test 4 (rep no)	Test 5 (rep no)	Test 6 (rep no)	Test 7 (sec)
1	LP, m		X	-.002	-.130	.368	-.066	-.456	.169	-.099
2			Y	.375	.213	-.152	-.565	.274	.338	.560
3		GCG	X	.146	.154	-.296	.005	.285	-.050	.073
4	MP, m		Y	.435	.534	-.453	-.303	.341	.047	.186
5			X	.130	.196	-.361	-.000	.359	-.056	.089
6	CP, m		Y	.375	.481	-.485	-.406	.437	.235	.375
7		toes		-.060	-.033	.183	-.121	-.150	.056	.034
8	LP,	should		-.012	-.119	.310	-.009	-.450	.167	-.099
9	rad/s	arms		-.176	-.275	.338	.223	-.572	.174	-.188
10		toes		-.077	-.121	.341	.021	-.397	.037	-.208
11	MP,	should		-.058	-.066	.295	-.076	-.318	.086	-.110
12	rad/s	arms		-.058	-.093	.273	.040	-.359	.053	-.192
13		toes		-.093	-.393	.540	-.048	-.432	.183	-.045
14	CP,	should		-.424	-.454	.346	.400	-.142	-.258	-.402
15	rad/s	arms		-.389	-.422	.410	.133	-.507	.211	.118
16	LP, N			.160	.149	-.000	.115	-.197	-.114	-.286
17	MP, N	GCG		*.622	*.578	*-.621	-.506	*.694	.161	.397
18	CP, N			-.554	-.527	.479	.332	-.032	-.475	-.376

Note: idem table 2; df=10; *p-0.05, r=576

The results of Pearson's linear correlation show strong connections between the indicators pf the dynamic characteristics of the force resultant during the multiplication of body posture at the maximum height of GCG flight (F, N) and Test 1 (cm), r=.622 at $p<0.05$, Test 2 – r=.578 at $p<0.05$, Test 3 – r=-.621 at $p<0.05$, Test 5 – r=.694 at $p<0.05$ and moderate connections between the indicators of the launching posture (LP, GCG, Ym), between the multiplication of posture (MP, GCG, Ym) and Test 2 (cm), between MP, GCG, F, N and Test 4 (no of reps); the connections between the other indicators are poor or even inexistent.

Table 4 highlights the connection level between the indicators of specific physical training and the performances obtained in the floor event regarding the difficulty, execution and final score.

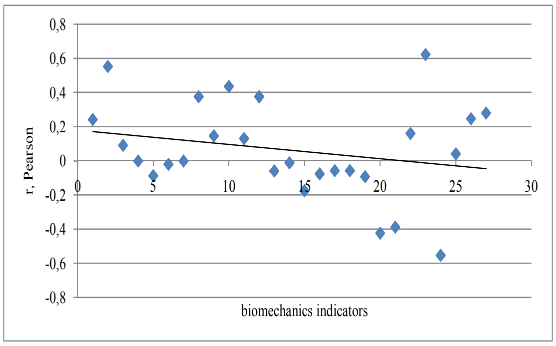
Table 4. Correlation of the specific physical training indicators with the performances achieved in the floor event (n= 12)

Item	Indicators	Strength - Speed			Strength			Specific Endur.
		Test 1 (cm)	Test 2 (cm)	Test 3 (sec)	Test 4 (rep no)	Test 5 (rep no)	Test 6 (rep no)	Test 7 (sec)
1	Difficulty, points	.040	.448	*-.706	.457	.442	-.510	-.335
2	Execution, points	.246	.137	-.040	.235	.072	-.411	*-.638
3	Final score, points	.279	.248	-.215	.303	.167	-.465	*-.658

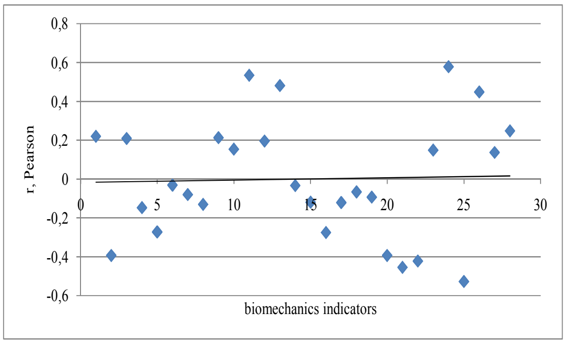
Note: df=10; *p-0.05, r=576

The results of Pearson's linear correlation reveal strong connections between difficulty (points) and Test 3 (sec) r =-.706 at p<0.05, between execution (points) and Test 7 (sec) r=-.638 at p<0.05 and between the final score (points) and Test 7 (sec) r=-.658 at p<0.05, moderate connections between difficulty and Test 6 while the connections between the other indicators are poor or even non-existent.

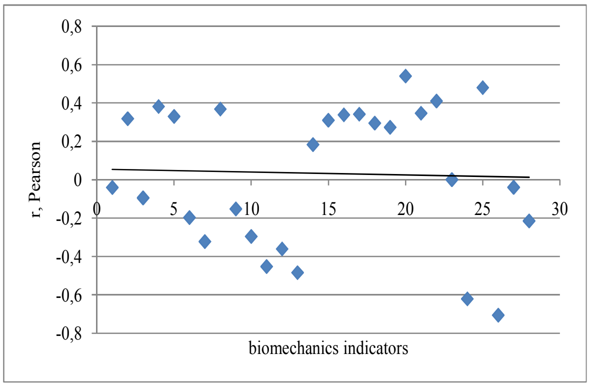
Figure 1 show the connection level between the indicators of the biomechanical characteristics in double salto backward and the "strength – speed" motor skill, regarding test 1 – standing long jump (2 attempts, cm), test 2 – standing high jump (2 attempts, cm) and test 3 – rope climb with no leg support (seconds).



a) Test 1- standing long jump (2 attempts, cm)



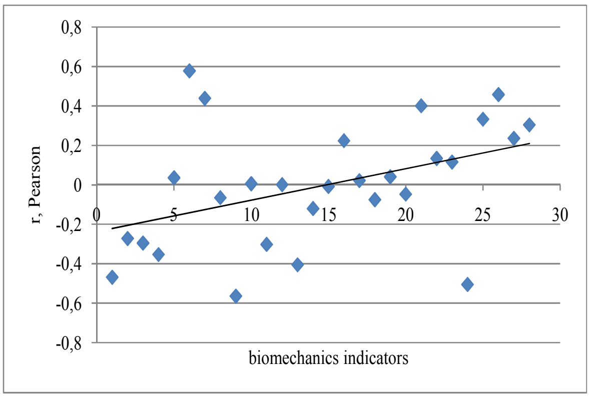
b) Test 2 - standing high jump (2 attempts, cm)

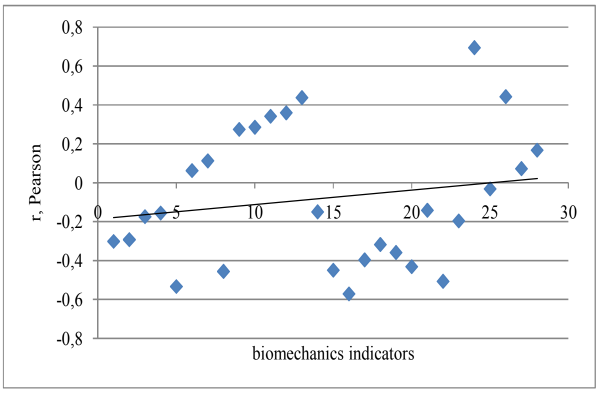


c) Test 3 - rope climb with no leg support (seconds)

Fig. 1. Graphical representation of the connections between the indicators of the biomechanical characteristics in double salto backward and the "strength – speed" motor skill

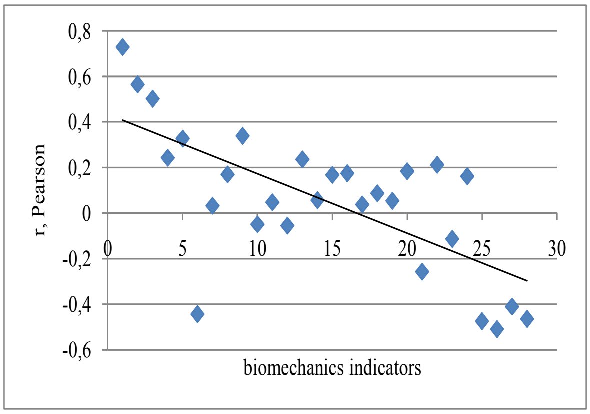
Figure 2 presents the connection level between the indicators of the biomechanical characteristics in double salto backward and the "strength" motor skill, regarding Test 4 – suspended on a fixed ladder, raising the legs up for 30 seconds (no. of repeats), test 5 – prone trunk extension for 30 sec. (no. of reps), test 6 – jump to handstand on the beam (2 attempts, no. of reps).





a) Test 4 - suspended on a fixed ladder, raising the legs up for 30 seconds (no. of reps)

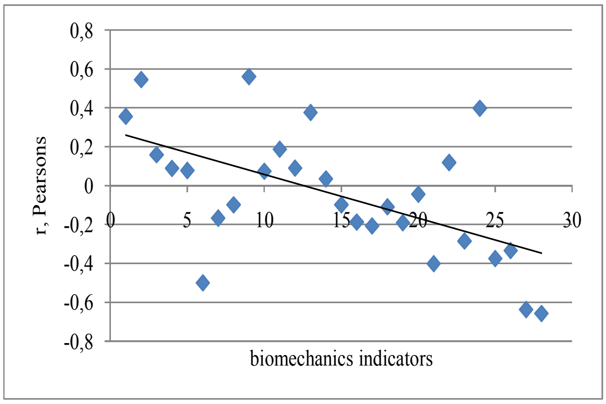
b) Test 5 - prone trunk extension for 30 sec. (no. of reps)



c) Test 6 - jump to handstand on the beam
(2 attempts, no. of reps)

Fig. 2. Graphical representation of the connections between the biomechanical characteristics indicators in double salto backward and the "strength" motor skill

Figure 3 shows the connection level between the indicators of the biomechanical characteristics in the double salto backward and the "specific endurance" motor skill, regarding test 7 – handstand hold on the beam (2 attempts, seconds).



Test 7 – handstand hold on the beam (2 attempts, seconds)

Fig.3. Graphical representation of the biomechanical characteristics indicators in double salto backward and the "specific endurance" motor skill

Discussion

The role of the technical training in gymnastics is very important and closely interrelated with the other components: a poor physical training entails a wrong and faulty technique, namely failure in competition, while a good technical training and a good physical training but lacking of proper psychological training lead to modest performances (Grigore, 2001). For that purpose, there are numerous concerns and studies where the authors address the following matters: the level of the sensorimotor coordination development (Potop & Carp, 2017), the basic physical and technical training of the gymnasts aged 12-15 years (Potop, 2013a); the methodological issues of motor learning based on the technology of transfer (Potop, 2013b; Potop, 2014); the principles of junior female gymnasts' macro-methodic training for sport exercises for all round competitions at the stage of specialized basic training (2015a, 2015b); the development of a long-term program for learning the

acrobatic exercises and a logical-structural scheme for performing these floor exercises based on the interaction of algorithms of the main and concrete goals of sports training for junior gymnasts aged 12 to 15 years (Potop & Boloban, 2016); the biomechanical analysis of the key elements of sports technique consistent with the results obtained in competition on the floor (Potop, et al., 2014); the effects of two manual guidance procedures on movement kinematics of a back handspring and a back tucked somersault following a round-off on the floor (Heinen, Vinken, & Ölsberg, 2010); an insight into the biomechanics of twisting (Fink, 1997); the contributions to the tilt angle reached at the mid-twist position used as measures of the twisting potential of various techniques (Yeadon, & Kerwin, 1999), the highlight of the biomechanical characteristics of the acrobatic element on floor and the comparison of floor exercise spring-types on a gymnastics rearward tumbling take-off (Potop, Niculescu, & Triboi, 2013; Sands, et al. 2013; 2014); examination of reaction forces transmitted to the upper extremities of high-level gymnasts during the round-off phase of the Yurchenko vault (Seeley & Bressel, 2005); comparison of the take-off's kinetic and kinematic variables between two acrobatic series leading to perform the backward stretched somersault (also called salto): round-off, flic-flac to stretched salto versus round-off, tempo-salto to stretched salto (Mkaouer, 2013); the use of e-training in mathematical modeling of the kinematic and dynamic characteristics of double back somersault on the floor (Potop, Jurat, Buftea, & Dorgan, 2017).
The analysis of the specialized literature also highlights different aspects regarding the age of the male and female participants in the Olympic Games and World Championships from 2003 until 2016 (Atiković, Kalinski, & Čuk, 2017); the impact of the control and planning system of the training process on the development of technical skills complex of the female gymnasts aged 12 to 15 years (Buftea, 2017); the potential benefits of biomechanics research to the contribution to injury prevention strategies in women's artistic gymnastics by identifying the mechanisms of injury and quantifying the effects of injury risk factors (Bradshaw & Hume, 2012). Evidence-based injury prevention interventions focused on reducing biomechanical loading during landings should be developed for gymnastics (Hume, Bradshaw, & Brueggemann, 2013). The specialists also focused on the biomechanical characteristics of impact loading and elbow kinematics and kinetics change as a function of technique selection (Farana, et al., 2014) and the description and comparison of lower extremity muscle activation in various tumbling sequences characterized by different body orientations (Mcneal, Sands, & Shultz, 2007).

Conclusions

This paper highlighted the horizontal variables of the connection level of the results linear correlation between the biomechanical characteristics and the test events for specific physical training and also the vertical variables between the level of motor skills development, the biomechanical characteristics and the performances obtained in the floor event by the female gymnasts aged 14 to 17 years. The review of the specialized literature reveals the concerns regarding the methodology of training and the macro-methods for learning the elements in women's artistic gymnastics. It also identifies the studies and biomechanical analyses of the technical elements in conformity with the current trends of artistic gymnastics development. The correlative linear analysis of the specific physical training indicators and the biomechanical characteristics of the double salto backward on the floor executed by the female gymnasts of 14 to 17 years old showed the connection level of the studied indicators and their influence on the technical execution.

Conflicts of interest

The authors declare that there is no conflict of interests.

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