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BIOMECHANICAL ANALYSIS OF PHASE ON THE REBOUND IN THE TRAMPOLINE

(Original scientific paper)

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Abstract

The studying of the trampoline sport technique is a necessary condition in order to improve the sport skills. According to the hypothesis of present examination, the rebound is amongst the most important phases of the trampoline exercises. The kinematic analysis of this part of the exercises will allow specialist to introduce more expedient corrections to the trampoline technique. The aim of this paper is to examine the rebound technique of different exercises and to establish typical biomechanical regularities. The object of the examination is trampoline exercises from different structural groups. The subjects under examination is the following kinematic parameters: the net downward moving, the alattitude and the length of the exercises, the average linear speed of the centre of gravity (COG), joint and segment angles of the key operating positions in the phases of the rebound. The contingent of the examination is a contestant part of the Bulgarian national trampoline team. Scientific methods such as video making, video cyclogram, kinematic analysis, pedagogical surveillance, expert evaluation, analytic and synthetic methods and mathematic methods are used for the sake of the examination. The main structural group of trampoline exercises are determined. The collected data from the kinematic examination is systematized in charts. The data formed on the examination, draw a conclusion that generalizes the typical regularities of the rebound that were looked at the every one of the examined structural groups.

Keywords: *kinematic analysis, structural groups of exercises, phase structure, sports technique, biomechanical regularities.*

INTRODUCTION

The leading tendencies in the trampoline development are connected to the increasing of the difficulty of exercises and routines, improvement of the technical condition of the apparatus used by the contestants and the increasing of the amplitude of the exercises. In the FIG Code of Points has been added a new element which relates to the components that formed the final score – „time flight". With regards to that, it is essential for successful competitive realization the sports specialists to apply more effective methods and approaches in the work for technical preparation. This imposes on sport technique studying of the exercises that are executed in the new improved conditions caused by the bettered competitive apparatus and by the changes in the judge`s rules. This task can be solved via biomechanical methods for research and analysis. From the reviewed literature sources, it`s clear that a lot specialists of different sports and disciplines are putting efforts in this direction. (Arakchiiski (Аракчийски), 2002, 2005; Gancheva (Ганчева), 2009; Gaverdovski (Гавердовский), 2002; Danilov (Данилов), 1983; Stanchev (Станчев), 2013).

According to the hypothesis of this elaboration, the rebound is amongst the most important phases of the trampoline exercises. In addition, it has a movement-forming role. The collected data from the executed kinematic research about this movement will help for a more detailed studying of the trampoline technique. Also, the data will extend the specialist possibilities to import corrections in the sports technique.

METHODS

The aim of this development is to research the rebound technique in the trampoline exercises of different structural groups and to establish biomechanical regularities for every one of them. In order this aim to be implemented, a video following the special requirements for biomechanical testing was made. The video is

Table 1. Biomechanical characteristics of the jumps that are object of the research

№	Description of the exercises	Difficulty	Rotation direction	Axis of rotation	Number of rotations around the lateral axis	Volumes of rotations around the long axis	Positions during a flight
1.	2141-O1	0,6	Front	Lateral and long	Single	180˚	Straight
2.	314-O1	0,6	Back	Lateral	Single	-	Straight
3.	2181-G1	1,1	Front	Lateral and long	Double	180˚	Tuck
4.	318-G1	1,0	Back	Lateral	Double	-	Tuck
5.	2183-CH1	1,5	Front	Lateral and long	Double	540˚	Pike
6.	3182-CH1	1,4	Back	Lateral and long	Double	360˚	Pike
7.	2185- CH1	1,7	Front	Lateral and long	Double	900˚	Pike, straight
8.	3186-O1	1,8	Back	Lateral and long	Double	1080˚	Straight
9.	21121-CH1	2,0	Front	Lateral and long	Triple	180˚	Pike
10.	31122-G1	1,9	Back	Lateral and long	Triple	360˚	Tuck

suitable for work with computer programmes. For the purpose to register the kinematical parameters which are subject of the research, are used several software products: Dartfish, Kinovea, Auto Cad. A comparative analysis of the rebound phase of the tested exercises was conducted.

The object under examination is ten exercises of different structural groups: №1 – straight somersault with a180˚ twist ; №2 – back somersault straight; №3 - double front somersault tuck with twist 180˚; №4 – double back somersault tuck; №5 – double front somersault pike with twist 540˚; №6 – double back somersault pike with twist 360˚ (180˚ in every somersault); №7 - double front somersault pike and straight with twist 900˚ (360˚ in the first and 540˚ in the second somersault); №8 – double back somersault straight with twist 1080˚; №9 – triple front somersault pike with twist 180˚; №10 – triple back somersault tuck with twist 360˚ (180˚ in the first and 180˚ in the third somersault);

The subject of the examination is kinematical parameters such as time and linear characteristics, the average linear speed of the COG at the time of the interaction with the net, joint and segment angles in the key operating positions, motive coordination during the rebound etc.

A contingent of the research is a contestant from the Bulgarian National Trampoline Team. The choice of the exercises for biomechanical analysis is made after acquaintance with literary sources, concerning the problems of the classification and compositional structure of the trampoline (Angelov (Ангелов), 2011, 2012; Danilov (Данилов), 1978). Based on that, the exercises object of the research, are systematized as well as the biomechanical signs that are more important to the sports technique (Table 1). All of the exercises are part of the connections and combinations but they did not form separate composition. Their choice is called by the strive to include in the research exercises which are part of the main structural group of jumps with different degree of difficulty.

RESULTS

The collected data of the kinematical research is systematized in Tables 2, 3, 4 and 5. A graphic of the average linear speed of the COG is made (Figure 2). In order to be prepared an analysis of fuller value, the rebound phase is divided in two sub-phases which include the contestant actions during the downwards stretching of the net and its resetting in starting position.

Table 2. Time and linear characteristics of the exercises

Exercises / Parameters	№1	№2	№3	№4	№5	№6	№7	№8	№9	№10
t (s) net down	0,16	0,16	0,16	0,16	0,12	0,16	0,16	0,16	`0,12	0,14
t (s) net up	0,16	0,16	0,16	0,16	0,2	0,16	0,16	0,16	0,16	0,16
t (s) rebound	0,32	0,32	0,32	0,32	0,32	0,32	0,32	0,32	0,28	0,3
t (s) flight	1,64	1,64	1,68	1,6	1,56	1,56	1,68	1,48	1,76	1,7
t (s) exercise	1,96	1,96	2,00	1,92	1,88	1,88	2	1,8	2,04	2
S (m) net	0,74	0,77	0,82	0,8	0,72	0,76	0,87	0,76	0,81	0,74
L (m) exercise	0,07	1,06	0,62	0,09	0,85	0,08	1,75	1,3	1,44	0,10
H (m) exercise	4,18	4,25	4,34	4,14	3,86	4,002	4,6	3,65	4,34	4,31

Table 3. Joints angle in key operating positions during the rebound

Joints angles (°)	Exercise 1			Exercise 2			Exercise 3			Exercise 4			Exercise 5		
	Operating poses			Operating poses			Operating poses			Operating poses			Operating poses		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Knee	174	176	178	154	177	179	171	169	179	161	177	110	164	165	175
Hips	144	172	163	128	176	152	124	171	140	152	175	180	127	170	145
Shoulder	137	175	133	137	170	169	113	173	126	134	180	140	128	166	121
Joints angles (°)	Exercise 6			Exercise7			Exercise 8			Exercise 9			Exercise 10		
	Operating poses			Operating poses			Operating poses			Operating poses			Operating poses		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Knee	169	177	134	158	168	176	158	175	124	161	163	179	165	176	142
Hips	152	189	148	130	167	149	129	177	203	137	160	133	135	179	213
Shoulder	142	175	174	120	168	130	89	174	166	141	174	112	109	167	174

Table 4. Segment angles in key operating positions during the rebound

Segment angles (°)	Exercise 1			Exercise 2			Exercise 3			Exercise 4			Exercise 5		
	Operating poses			Operating poses			Operating poses			Operating poses			Operating poses		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Shank	86	84	89	98	95	90	85	75	92	102	93	122	83	72	84
Torso	56	79	74	125	88	63	38	77	52	110	95	52	45	78	54
Segment angles (°)	Exercise 6			Exercise 7			Exercise 8			Exercise 9			Exercise 10		
	Operating poses			Operating poses			Operating poses			Operating poses			Operating poses		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Shank	104	99	118	85	76	87	98	92	114	81	76	87	99	98	116
Torso	122	88	40	56	74	52	127	90	35	57	73	41	129	93	45

Table 5. Averarge linear speed of COG during the rebound at the ten tested exercises

t (s)	V (m/s)									
	1	2	3	4	5	6	7	8	9	10
0,04 s	7,21	8,42	7,78	7,56	9,14	9,01	9,18	6,76	7,7	8,02
0,08 s	4,27	6,39	9,66	7,7	5,39	6,68	8,36	6,47	6	3,57
0,12 s	2,28	3,96	3,42	5,98	2,82	2,97	3,5	3,68	5,37	3,89
0,16 s	2,96	0,28	1,01	1,95	0,84	1,11	1,47	0,92	0,01	3,08
0,20 s	3,98	4,58	2,5	2,59	4,03	2,58	2,73	3,5	2,97	4,94
0,24 s	9,23	7,05	7,47	5,8	7,02	5,93	7,29	5,6	7,55	7,41
0,28 s	6,73	6,8	6,71	6,94	6,2	8,02	9,34	7,66	7,95	7,32
0,32 s	6,38	8,17	8,96	7,76	8,5	6,83	6,95	7,28	-	-

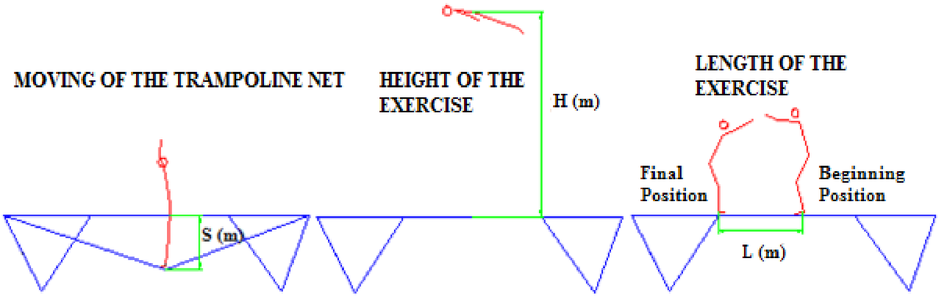

Figure 1. Linear characteristics, subject under examination.

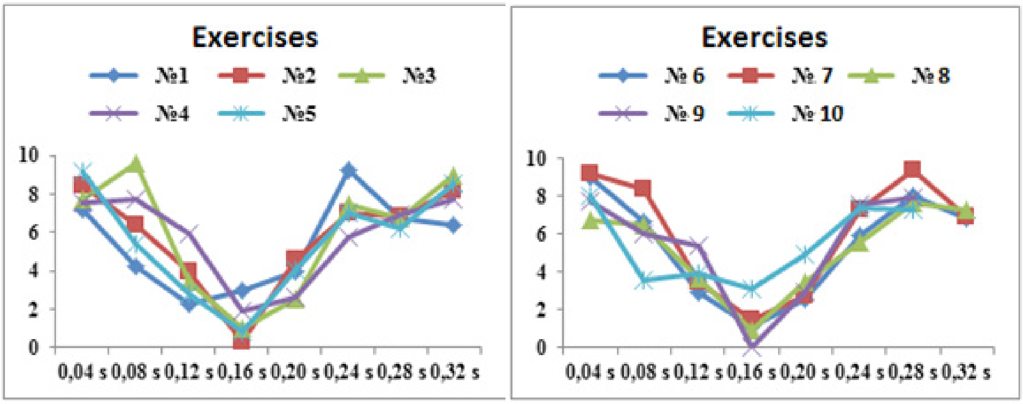

Fig. № 2. A graphic of the average linear speed of the COG during the rebound

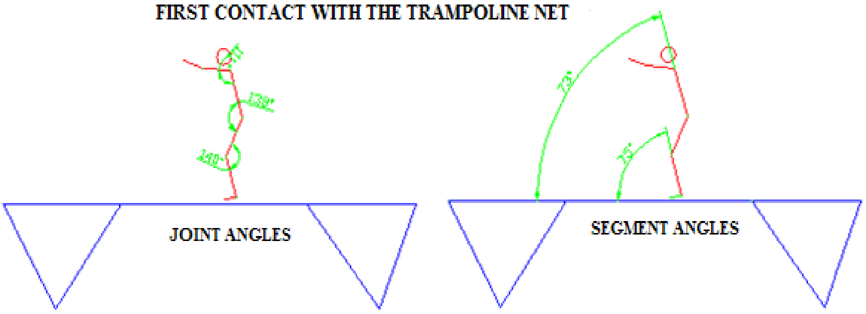

Figure 3. Joint and segment angles at the time of the first contact with the support

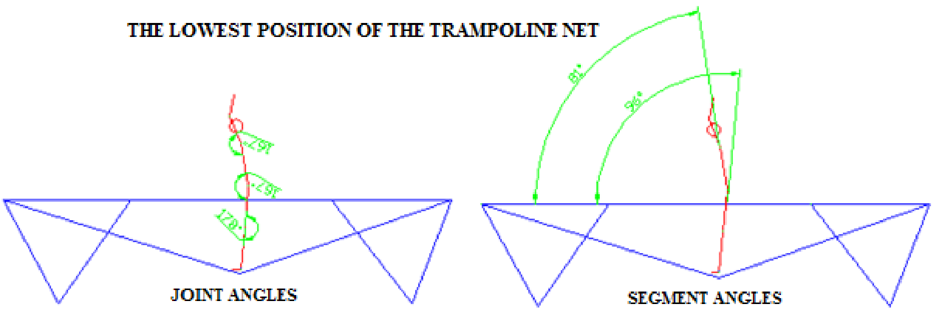

Figure 4.. Joints and segment angles during the lowest position of the net

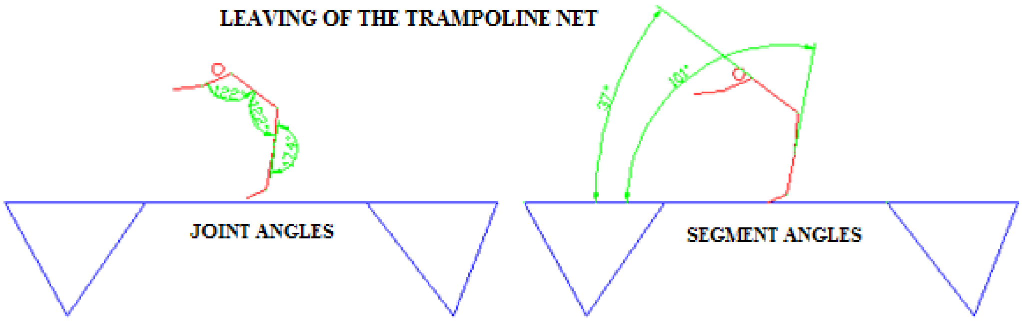

Figure 5. Joints and segment angles during the support leaving

DISCUSSION AND CONCLUSION

The analysis of the researched parameters has begun with reviewing of the *time characteristics.* From them it is examined the duration of the rebound and its constituent parts, the actions in position without support and the whole exercise (Table 2). The research has established that the duration of the rebound phase is in the borders of 0,28 to 0,32 sec. At most of the exercises the both parts of the rebound are with equal duration of 0,16 sec. At some exercises including the both triple somersaults, the first sub-phase of the rebound is shorter – 0,12-0,14 sec. The registered duration of the phase without support is in the range of 1,48 to 2,04 sec. The duration of the individual exercises is at the interval of 1,8 to 2,4 sec. The exercise „double back somersault straight with twist 1080°" which is with the shortest duration – 1,8 sec is with the biggest volume of rotation around long axis. The „triple front somersault pike with twist 180°" is with the longest duration – 2,4 sec where the number of rotations around lateral axis are predominating.

The examined linear characteristics in the development are the downward net moving, length and height of the jump (Table 2, Figure 1). From the collected data can be resumed that the registered net moving at the ten jumps is in the range of 0,72 to 0,87 m. The least stretching of the net is during the jump №5 and the biggest is during the jump №7. Characteristically, the both exercises are from different structural groups. The direction of the turning is forward, the operating position of the flight is tuck and the rotation is combined. The difference between them is in the volume of rotation around the lateral axis – 540° and 900°. It can be concluded that, there is no connection between the structural group, the difficulty of the exercise and the size of the net moving. Therefore, a proportional dependence between the bigger way of the net downwards and the amplitude of the jump is established.

The examination of the height of the exercises proved that it is in the range of 3,65 to 4,6 m. The shortest jump is № 8. Its difficult is 1,8 points. The volume of the rotation around the lateral axis is 720° backward and around the long axis – 1080°. The position of the body during the flight is straight. The highest execution is of exercise № 7. There, the rotation is combined as well. This is double somersault with twist 900°. The direction of the rotation is forward. The operating positions in the flight are „pike" and „straight". Its coordination complexity is 1,7 points.

Interesting results are estimated regarding the length of the jumps. The values of this characteristic according to the laws of the mechanics are in the reverse proportionality dependence with the height of the exercise. The interval of the registered length of the jumps is with the lowest border of 0,07 m and with the highest – 1,75 m. A curious fact is noted. The exercise with the biggest length between the starting and ending position is the highest one executed – 4,6 m. This means that corrections of the angle characteristics during the interaction with the support can increase its amplitude to a large degree.

Another researched parameter is the *average linear speed* of the COG during the interaction with the trampoline net (Table № 5, Fig. № 2). The examination confirmed that in the stretching of the net during its downward movement, the average linear speed of the COG of the athlete decreases. In the opposite direction, the upward net movement to starting position gradually increased the speed of the COG. In the most tested exercises, the value of the average speed of COG at the moment of the contact with the net is similar to the moment of the support leaving.

Next in the research are examined two angle characteristics – joint and segment angles (Figure 3, 4 and 5). *Joint angles* give information about the configuration of the body and about the coordination between the separate sections of the moving system. The angles in the knees, hips and shoulders joints are registered in the key operating positions: during the first contact with the support, during the lowest position of the net and during the support leaving. It can be noted that with the increasing of the exercises difficulty, the angle in the knee joints decrease at the time they contact the support. Its values are in the range of 154° to 174°. The scope of the angles in the hips joint is determined by the minimal value – 124° and the maximum – 152°. The amplitude in the shoulder joint in this part of the rebound is in the range of 89° to 142°. The examination categorically has proved that at the maximum stretching of the net to the lowest point, the configuration of the body is with the biggest extend in all of the three tested joints. It can be noted that, in the exercises with forward rotation the position of the body is more bent and in these with backward rotation – more stretched. At the time of leaving the support, in the jumps with forward rotation, the legs are more stretched and the angle in the shoulders more closed. It can be observed, an opposite dependence at the backward rotations.

The segment angles (between the horizontal and a segment) give information about the orientation of the body according to the support. In this research are registered segment angles of the shank and torso in the indicated three key operating positions. It was established that at the first contact with the net the segment angles of the shank and torso in the exercises with forward rotation are with lower values and the jumps with backwards rotation with higher values.

An interested regularity was stated in the second operating position at the time of the lowest point of the net. The both segment angles in the most of the exercises are with similar values. This proved that in this part of the rebound the body is oriented in a line. The collected data give a proof that the third operating position at the moment of support leaving in the jumps with less difficulty and these with forward rotation, the shank is oriented around the vertical. At the more complex exercises with a backward rotation, the value of this angle increases to 114-122˚. The segment angle of the torso in this final part of the rebound is with the values from 35˚ to 74˚.

Lastly, the motive coordination at the time of the interaction with the support, consisting in the performance of flexion-extension actions of the limbs during the net movement in both directions was examined. It is observed that in all of the exercises the net is met with bent knees and raised hands. The net movement up and down and the extension actions of the limbs are not synchronic. At some of the exercises, the maximum extension is happening in the lowest position of the net and in the others at the upwards movement of the net. In several exercises in the lowest point of the support is established a short pause involving the extension of the body in the all of the three joints and setting of direction.

In conclusion, the conducted research gives information about the kinematic structure of the rebound phase in the trampoline. The rebound doesn't have model forming value because of the limited contingent of research. Also, it is correct to underline that the established regularities are made based on biomechanical research in the conditions of different competitive condition. The mechanic of the movements and parameters of the tested exercises would undergo metamorphosis if they are included in the links of exercises and in different part of the whole competitive combination.

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