

CHANGES IN TECHNIQUE OF HANDSPRING DOUBLE SALTO FORWARD TUCKED PERFORMED ON HORSE AND VAULTING TABLE

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ABSTRACT

Aim of the research was to determine changes in technique parameters while performing handspring double salto forward tucked (Roche) on old horse and new vaulting table. On a sample of 9 vaults performed in 2000 World Cup in Ljubljana on horse and 9 vaults performed at World championship in Debrecen on vaulting table we made a series of t-tests for biomechanics kinematics parameters. There are differences in many variables, but most important are those related to the support phase (position of hands, take off vertical velocity) which also causes better outcome during the flight and landing. New vaulting table is really much better apparatus than the horse as has better place for support, which makes easier production of angular momentum (inclined table) and higher vertical take off velocity.

Key words: artistic gymnastics, vault, horse, table, biomechanics, double salto

INTRODUCTION

At World Championship 2001 in Ghent FIG (FIG, 2001) changed their tradition and they replaced old horse with vaulting table (Figure 1). After pre tensioned apparatus in '50 this is the biggest change in apparatus design.

By FIG norms vaulting horse is 160 cm long, 35 cm wide and 135 cm high (FIG, 1989). Vaulting table is 95 cm wide and 95 to 105 cm long and 135 cm high. Wider and shorter table is safer [4]. Upper area of the table is slightly inclined (5 degrees). New apparatus has more advantages with wider and slightly inclined support area, what gives gymnast better anatomical support, and better position for arms take off action (Figure 2) [1, 4].

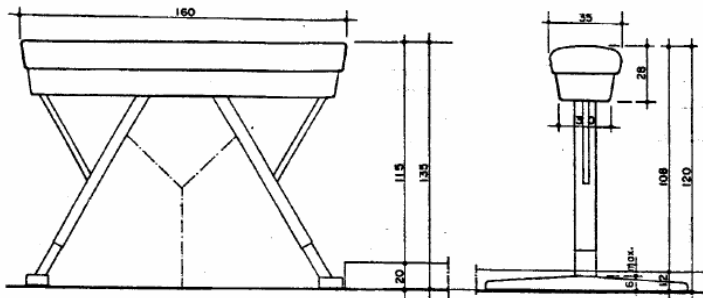


Figure 1. Vaulting horse and vaulting table (FIG, 1989) [2]

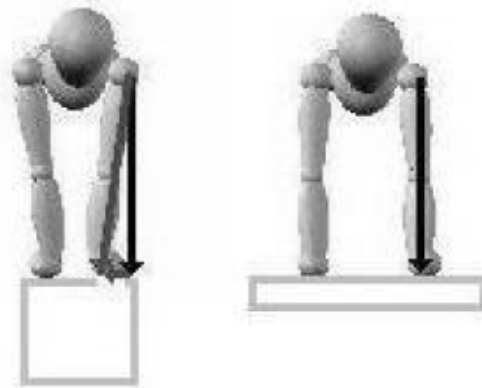


Figure 2. Support position on horse and vaulting table [1]

As we were aware that support is more efficient on new vaulting table, we were searching if beside support are also some other changes in technique of top level vaults and how this change reflects on other biomechanics variables. One of the most difficult jumps nowadays is handspring double salto forward tucked (FIG, 2006), which gymnasts performed on old horse and new vaulting table, within such quantity that we can do statistical analysis.

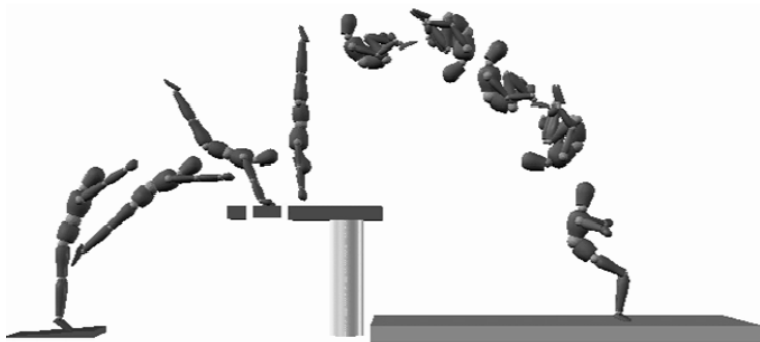


Figure 3. Handspring double salto forward tucked (Roche) [1]

MATERIALS AND METHODS

Sample of gymnasts were those gymnasts who have performed handspring and double salto forward tucked at World Cup competition in Ljubljana 2000 (N = 9) and those gymnasts who have performed same type of vault at World Championship in Debrecen 2002 (N = 9).

Kinematic analysis were done with APAS-Ariel performance analyses system (Ariel Dynamics Inc., San Diego, CA). We used Sušanka, Otahal, Karas [8] 15-segment body model defined with 17 points. All the jumps were recorded during the competition with two orthogonal SVHS cameras with 50 frames per second. All data were smoothed with digital filter of range 7. We calculated trajectories, velocities, time and angles of important positions in following phases of the vault: support on springboard, the first flight, support on apparatus, the second flight and landing; all together we defined 104 variables.

Statistic analysis were done with SPSS (Statistical Package for the Social Sciences, 12.0, Chicago, IL, USA). First we calculated differences in quality of jumps between horse and table. Good jump meant jump without fall (on table were 6 and on horse 5 good ones) and bad jump was defined as jump with fall (on table were 3 and on horse 4 bad ones). Calculated χ^2 (0,12; non significant differences) showed no differences in quality of jumps. For each variable we calculated descriptive statistics, than F-test between both groups and considering results of F-test we calculated t-test (for equal or unequal variances), only significant differences in variables are introduced.

RESULTS AND DISCUSSION

Table 1. Results of springboard support phase variables

		Table	Horse	p(F)	pt-test
velocity BCG Vx 1. touch springboard <i>[m/s]</i>	X	7.967	7.581	0.562	0.010
	MAX	8.350	7.875		
	MIN	7.575	7.150		
	SD	0.283	0.229		
	SE	0.188	0.169		
velocity BCG Vy 1. touch springboard <i>[m/s]</i>	X	1.113	0.784	0.674	0.038
	MAX	1.350	1.025		
	MIN	0.725	0.450		
	SD	0.236	0.200		
	SE	0.172	0.158		
velocity BCG Vxyz 1. touch springboard <i>[m/s]</i>	X	8.049	7.623	0.531	0.008
	MAX	8.459	7.932		
	MIN	7.624	7.198		
	SD	0.298	0.237		
	SE	0.193	0.172		
velocity BCG Vx last touch springboard <i>[m/s]</i>	X	5.042	4.667	0.739	0.062
	MAX	5.625	5.350		
	MIN	4.525	4.250		
	SD	0.328	0.370		
	SE	0.202	0.215		
velocity BCG Vy last touch springboard <i>[m/s]</i>	X	4.654	4.597	0.368	0.945
	MAX	4.725	4.925		
	MIN	4.300	4.200		
	SD	0.138	0.192		
	SE	0.131	0.155		
velocity BCG Vxyz last touch springboard <i>[m/s]</i>	X	6.868	6.562	0.433	0.031
	MAX	7.346	6.875		
	MIN	6.475	6.351		
	SD	0.244	0.183		
	SE	0.175	0.151		
angle thunk / thigh hip <i>[degrees]</i>	X	103.0	111.9	0.910	0.005
	MAX	111.9	118.3		
	MIN	92.6	101.4		
	SD	5.9	5.7		
	SE	0.9	0.8		

Velocity (in xyz) of gymnasts BCG (Body Centre of Gravity) at touch down on springboard jumping on horse is 7.623 m/s and 8.049 m/s on table, the difference of 0.426 m/s is significant Velocity (in xyz) of gymnasts BCG at take off from the springboard jumping on horse is 6.562 m/s and 6.868 m/s on table, lose of velocity is for both similar (horse 1.162 m/s and table 1.172 m/s). At touch down BCG velocity in x and y axis is higher for table and also hip angle show more open gymnast position, while at take off persist only the difference in BCG velocity (in xyz). Differences in velocities in x and y axis are not significant, what shows quite an interesting variance, how gymnasts gain angular momentum on very individual basis. Higher BCG velocity on springboard at touch down and take off table can be explained by famous Fitts law [3, 7], which says bigger the area to reach higher velocity can be used; higher velocity means lower control and lower precision. As the horse has smaller support area than table [1, 4, 5, 6] handspring double salto forward tucked is performed with lower BCG velocity on the horse according to Fitts law.

Table 2. Results of support phase variables

		Table	Horse	p(F)	pt-test
Support time	X	0.162	0.162	0.078	1.000
	MAX	0.180	0.200		
	MIN	0.140	0.140		
	SD	0.012	0.023		
	SE	0.039	0.054		
[s]					
Hand grip	X	0.439	0.176	0.012	0.000
	MAX	0.490	0.213		
	MIN	0.325	0.149		
	SD	0.054	0.020		
	SE	0.082	0.050		
[m]					
Proportion Shoulders wide/Support wide	X	0.992	2.494	0.179	0.000
	MAX	1.314	2.822		
	MIN	0.859	2.127		
	SD	0.143	0.236		
	SE	0.134	0.172		
[m]					

		Table	Horse	p(F)	pt-test
Velocity	X	3.929	3.644	0.915	0.379
BCG	MAX	4.675	4.375		
V_x	MIN	3.225	3.200		
Take off	SD	0.438	0.421		
<i>[m/s]</i>	SE	0.234	0.229		
Velocity	X	4.146	3.803	0.601	0.005
BCG	MAX	4.425	4.125		
V_y	MIN	3.900	3.500		
Take off	SD	0.183	0.222		
<i>[m/s]</i>	SE	0.151	0.167		
Velocity	X	5.724	5.278	0.492	0.037
BCG	MAX	6.235	5.819		
V_{xyz}	MIN	5.257	4.743		
Take off	SD	0.286	0.368		
<i>[m/s]</i>	SE	0.189	0.214		

On the table gymnast has arms almost parallel and orthogonal to support, what is most efficient kind of support. Proportion between shoulders and hand support changed as we expected [1, 4]. Better position of arms gives them position to generate higher take off force what shows out also as higher BCG velocity in y axis. By calculating difference of force between vertical component and horizontal component; vertical component of force on table is 3% higher. Inclined table (5%) rises orthogonal force on table, what gives by reaction force of table better take off results (higher take off force, higher angular momentum [5]).

Results of support phase show that support time remained almost identical on vaulting table, therefore it can be considered, as elasticity of new vaulting table was not changed, that 0.162 second is somewhat ideal time for force impact [1].

Significant difference is between velocity at take off from apparatus. Higher vertical velocity is on table, as well as velocity in space. Similar results has found BY Takei [9]. Angles between body segments (head, arms, trunk, legs) has not changed significantly.

Table 3. Results of flight phase variables

		Table	Horse	p(F)	pt-test
Angular velocity From take off To 1st salto <i>[degrees./s]</i>	X	800.5	800.2	0.332	0.318
	MAX	822.9	830.0		
	MIN	728.0	767.4		
	SD	29.5	20.7		
	SE	1.9	1.6		
Angular velocity 1st salto to 2nd salto <i>[degrees./s]</i>	X	1104.5	1075.2	0.584	0.972
	MAX	1200.0	1125.0		
	MIN	1000.0	1000.0		
	SD	64.1	52.5		
	SE	2.8	2.6		
Angular velocity 2nd salto to Touch down <i>[degrees./s]</i>	X	693.2	797.7	0.412	0.032
	MAX	820.9	960.5		
	MIN	605.0	606.0		
	SD	86.0	116.2		
	SE	3.3	3.8		
Time Of flight <i>[s]</i>	X	1.056	1.022	0.503	0.021
	MAX	1.080	1.060		
	MIN	1.000	0.980		
	SD	0.024	0.031		
	SE	0.055	0.062		
Time from take off to max contraction <i>[s]</i>	X	0.230	0.258	0.010	0.027
	MAX	0.240	0.320		
	MIN	0.220	0.220		
	SD	0.011	0.029		
	SE	0.036	0.060		
Time from 2nd salto to touch down <i>[s]</i>	X	0.247	0.209	0.055	0.005
	MAX	0.260	0.220		
	MIN	0.200	0.200		
	SD	0.022	0.011		
	SE	0.052	0.036		
Angle trunk Thigh Max. <i>[degrees]</i>	X	49.3	42.5	0.864	0.023
	MAX	57.6	53.1		
	MIN	42.5	33.2		
	SD	5.9	5.5		
	SE	0.9	0.8		

		Table	Horse	p(F)	pt-test
Angle	X	60.4	49.3	0.437	0.001
Thigh	MAX	69.2	58.3		
Calf	MIN	54.1	40.4		
Max.	SD	4.8	6.3		
<i>[degrees]</i>	SE	0.8	0.9		

Higher vertical take off force on table is reason for higher peak BCG height in the second flight, higher is BCG after finishing the first and the second salto on table. In a whole the time for the second flight is on table longer.

On the table is also faster bending from the take off up to the maximum tuck position in salto. Reason is because angles on horse are smaller, therefore gymnast on table is more open (moment of inertia is higher). Similar results were obtained also by Takei [9].

Surprisingly angular velocity during first and second salto is for both same, however hip and knee angles during salto are significantly different, as during vaults from vaulting table gymnasts are more open, what means, that during flight phase they have higher angular momentum [5, 10].

On table is extended time from finished second salto to the first contact at landing, as BCG height after the second salto on horse is 2.07 m and on table 2.29 m. With higher BCG position and with stretching prior the landing gymnast on table lowers angular velocity what gives him better chances to control landing.

Hip and knee angles at the moment of first touch down are higher on table (gymnasts is more open). Also on table BCG is in moment of touch down higher for 0.12 m.

New vaulting table allows gymnast to gain higher runway velocity, better anatomic-functional position of arms, and therefore higher vertical velocity from apparatus and angular momentum (inclined table), what results in longer time of flight, higher amplituded of flight and better position to prepare for landing [1, 5].

Table 4. Results of landing variables

		Table	Horse	p(F)	pt-test
Angle	X	137.7	106.6	0.731	0.006
Trunk	MAX	165.0	147.1		
Thigh	MIN	98.5	85.2		
Touch down	SD	22.2	19.6		
<i>[degrees]</i>	SE	1.7	1.6		
Angle	X	133.0	108.7	0.441	0.009
Thigh	MAX	152.4	135.9		
Calf	MIN	94.1	88.8		
Touch down	SD	19.6	14.8		
<i>[degrees]</i>	SE	1.6	1.4		

From our results we can conclude that new vaulting table significantly changed performances of gymnasts. However there might be also a catch. Our investigation was performed in time, where there was not a lot gymnast who can perform such vault and accommodation to the new vaulting table was not so world wide spread, and only best gymnasts were performing handspring double salto forward tucked. As gymnast easier gains during the support higher angular momentum, this can be dangerous for those gymnasts who are not physically, technically and mentally prepared for such a difficult vault as new vaulting table gives them blind self confidence.

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