KEY PARAMETERS OF THE 2nd FLIGHTPHASE OF THE TSUKAHARA WITH SALTO BACKWARD PIKED

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For a high final score the gymnast need a high difficulty, but this is equivalent to a potential injury risk. Therefor purpose of this study was to identify key parameters of the 2nd flight phase for a safety execution of the Tsukahara with salto backward piked. Nine world class athletes were selected from Videos of two competitions with international participation. Each vault was examined with a 2D kinematic analysis from contact phase of the vaulting table up to the landing. With the help of these evaluated reference values coaches and scientist are able to compare the execution of their gymnasts with the help of a motion analysis to check for their safety and the successful learning of the vault.

KEY WORDS: Artistic Gymnastics, vault, biomechanical analysis, Tsukahara salto backward piked.

INTRODUCTION: The aim of a gymnastics competition is to perform a difficult exercise with nearly perfection for a high final score. The apparatus vault is unique, because gymnasts show only one element contrary to the other apparatuses with a lot of different elements. The Tsukahara with salto backward piked (Figure 1) is one of the most difficult vaults with a high starting value of 6,0 points (Fédération Internationale de Gymnastique [FIG], 2013, p. 101). Otherwise it is also a vault with a high risk of potential injury. Therefore the purpose of the study was to determine parameters for a safety performance of the vaults 2nd flight phase (2nd FP).
First of all we have a look for international publication to this vault. Although vaulting is the most researched and best understood apparatus (Prassas, Kwon & Sands, 2006), but there were just a few studies only as abstract (Lim, 2004; Yeo, 2003; Wei, 2001), or as a qualitative describing (Čuk & Karáčsony, 2004) of the vault. The abstracts main statements were: a fast approach, a short 1st and a large 2nd FP (Lim, 2004).
Since there are no data on the Tsukahara with salto backward piked, it was the intention of the study to generate reference values for a safety execution of this vault.

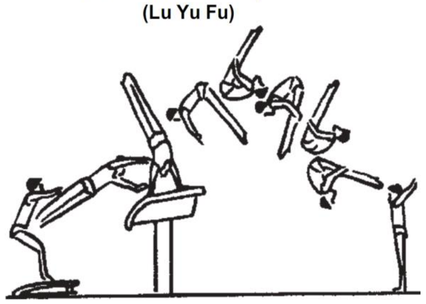

Figure 1: Tsukahara with salto backward piked (FIG, 2013, p.101)

METHODS: To identify the key parameter of the vault nine world class athletes (Table 1) were selected from two different gymnastics competitions: World Championships Stuttgart 2007 and European Championships Berlin 2011. Primarily the cause of selection was not the high final note, but rather the safety execution of the vault. Therefore not only stick landings were selected, but also vaults with steps backward were taken into account. The mean judges score for the 9 vaults was 9,017 (SD: 0,491).

Table 1
Number, age, height and weight of the selected participants

N	Age (yrs)		Height (m)		Mass (kg)	
Gymnasts	M	SD	M	SD	M	SD
9	24.2	4.7	1,64	0,04	62,7	5,1

In a pilot study (Brehmer, Naundorf & Heyne, 2012) a 3-dimensional and a 2-dimensional analysis of the Tsukahara with salto backward piked were compared. The differences between the two methods were 1% for the maximum height of the Centre of Mass and 3% for the angular momentum during the second flight phase. A comparison of the joint angles

only for the second flight phase show differences of 1° on average and about 6° at maximum for the crucial hip angle. Based on these results and under recognition of the time for manual digitization we choose the 2-dimensional analysis. Nevertheless, it must be noted that there are higher differences in the shoulder angle between 2D and 3D. This is due to the differences between the plane of motion and digitized angular plane. For our aim, to examine parameters for safety performance the shoulder angle plays only a minor role.
All executions of the vault were recorded by a HD Camcorder (Panasonic AG-HMC 151) with a resolution of 1280x720 px and a 50 Hz video frequency. The camera position was perpendicular to the vaulting table. The picture was chosen as large as possible, but this made it necessary to pan the camera from 10 m in front to 5 m after the vaulting table (Figure 2).

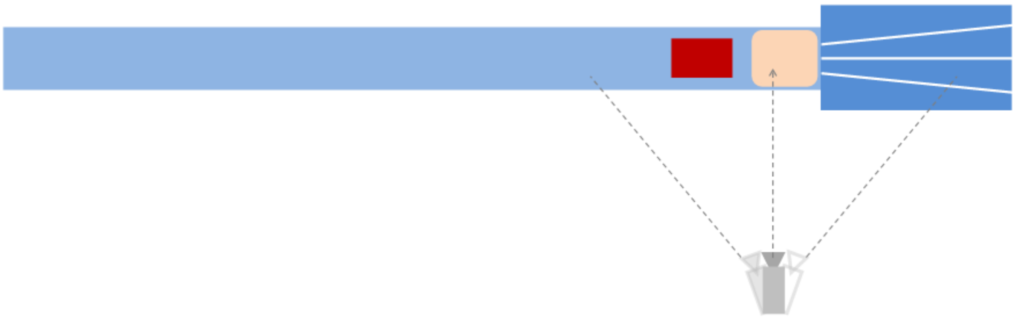

Figure 2: Schematic diagram of the recording conditions of the panned camera.

For the video analysis the movement area was calibrated by a 3-dimensional calibration cube (1.89 x 1.89 x 2,26 m) which was digitized in front of the vaulting table and behind the table on the landing mat (Kindler & Drenk, 2007).
The digitalization of the movement made on the basis of 7 body points (yellow circles in figure 3) of the visible side of the body: head (1), shoulder (4), elbow (7), wrist (9), hip (13), knee (15) and ankle (17). The connected body points made a six-segment model as basis for calculating the parameters. The reference point was set at the surface of the landing matt right under the vaulting table (red point in figure 3).
The run up velocity were measured with a laser velocity guard additionally (Naundorf, Brehmer, Knoll, Bronst & Wagner, 2008).

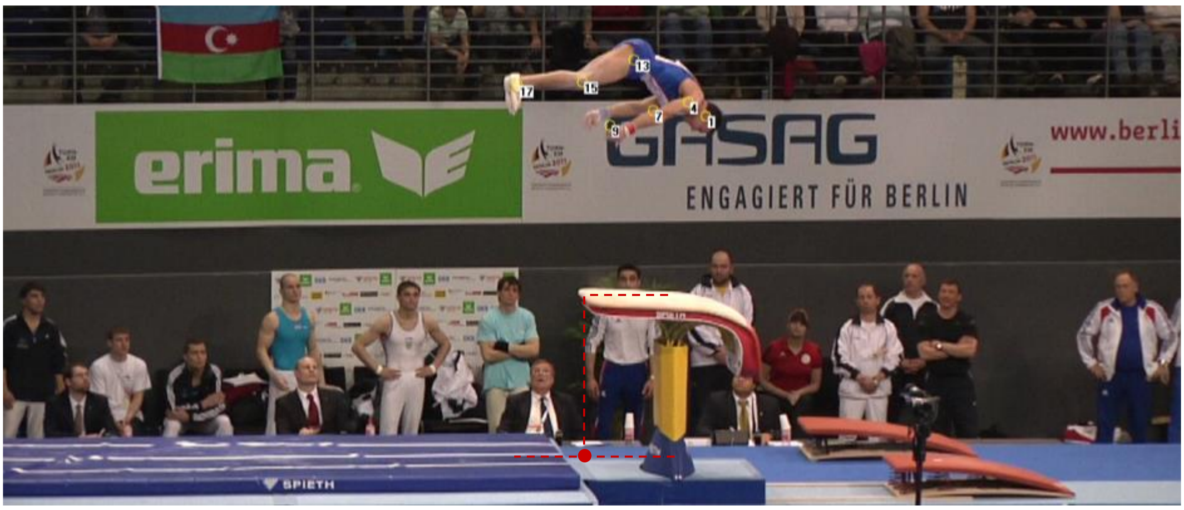

Figure 3: Position with digitized body points and the reference point (red dot).

The measured and calculated parameters, there shortcut and description are shown in Table 2 in chronological order to the motion sequence. Mean (M), standard deviation (SD), minimum (min) and maximum (max) values and the 95% confidence interval (CI95) were calculated using SPSS 19. The CI95 shows a range for other gymnasts to reach.

Table 2
Parameter description, in chronological order to the motion sequence

Item	shortcut	Unit	description
running velocity	v_{5-7}	m/s	mean running velocity from 7 to 5 m in front of the vaulting table
time of flight 2nd FP	t	s	time from 1st picture after table take off to 1st picture in contact with landing surface
height of flight 2nd FP (CM)	h_{max}	m	maximal height of centre of mass (CM) in 2nd FP
CM elevation	h_{elev}	m	difference between CM height at take-off and h
landing height (CM)	h_{land}	m	CM height at 1st landing contact
relative angular momentum	L_{rel}	Nms	angular momentum normalised to a standard gymnast with height 1.60 m and body mass 55 kg
theoretical number of stretched somersaults	$n_{str.SSi}$		mathematical summary from L_{rel}, theoretical moment of inertia of a stretched body, h_T, h, h_L and g
minimal hip angle	min α_H	°	minimal angle between knee-hip-shoulder during 2nd FP
take off angle from table	α_{TOT}	°	angle between vertical line and line from shoulder to ankle
somersault rotation angle 1 m above landing surface	α_{1m}	°	somersault rotation angle at the moment, when CM is 1 m above the landing surface

RESULTS & DISCUSSION: The results of the analysis of the world class gymnasts are shown in Table 3.

Table 3
Results for all measured parameter from 9 vaults

Item	M	SD	Min	Max	95% confidence interval	
					lower	upper
v_{5-7}	8,3	0,2	8,0	8,6	8,2	8,5
t	1,03	0,02	1,00	1,06	1,02	1,05
h_{max}	2,72	0,08	2,62	2,81	2,66	2,78
h_{elev}	0,76	0,07	0,64	0,86	0,71	0,81
h_{land}	0,56	0,06	0,47	0,64	0,51	0,61
L_{rel}	66,3	3,1	62,3	71,2	63,9	68,7
$n_{str.SSi}$	1,53	0,09	1,40	1,64	1,46	1,60
min α_H	62,4	6,9	52,0	75,0	57,1	67,7
α_{TOT}	-19,1	8,0	-29,0	-8,0	-25,2	-13,0
α_{1m}	788,3	24,2	759,0	828,0	769,7	807,0

For the first time a study analysed more than one gymnast with the Tsukahara with Salto backward piked to get reference values for the 2nd FP. These values were extracted from the execution of nine world class athletes with a save performance. Especially on vault with a high risk of injury these biomechanical data can help to decide if a gymnast can do a vault on a competition like surface or to train a little bit longer in a foam pit or with soft gymnastics mats.

Nevertheless should be mentioned, that gymnasts can perform such a vault successfully without reaching all parameters in reference range. They are able to compensate one insufficient parameter with another. Thus these values should not be seen as a dogma, but rather as a chance to check the gymnast's performance under safety training conditions

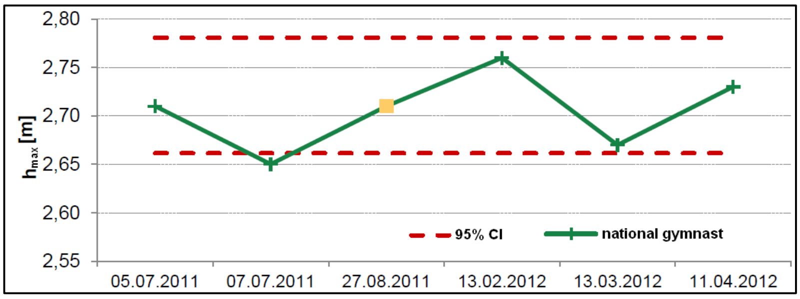

Figure 4: Example of a national gymnast compared to the world class gymnasts in maximum height in 2nd FP

(foam pit). Such an evaluation was made with a national gymnast, with the result that he didn't reach the range of the reference values for the most parameters. His vault was high enough (Figure 4), but he did not reach for instance the lower 95%CI for the angular momentum. However he was able to compensate this lack of performance with a tighter piked position and thus a faster angular velocity. But the higher angular velocity is a disadvantage for a good landing to earn high judges values and impeded a successful execution of this gymnast in competition.

CONCLUSION: By analysing the execution of the Tsukahara with salto backward piked of nine world class athletes there were created reference values for a safety execution. Coaches and scientist can use this data to compare the performance of their gymnasts and provide guidance for a safe and successful execution of the Tsukahara with salto backward piked.

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