PROPOSED METHOD OF IDENTIFICATION OF TECHNICAL ERRORS IN ARTISTIC GYMNASTIC: CASE STUDY

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Abstract

The aim of this study was to identify technical errors in artistic gymnastics, with comparative kinematic analysis of two gymnasts of different levels of success. The sample for comparative kinematic analysis consisted of ten attempts basket to handstand performed without technical errors by top gymnast and ten attempts performed with technical error by the middle-class gymnast. Kinematic analysis was performed with the help of 3-D video system for the APAS kinematic analysis, using a model with 17 points and 15 segments. Statistical significance of obtained mean differences between the two groups of attempts was determined using t-test for independent samples. Obtained results indicated that attempts performed flawlessly have significant greater speed of center of body gravity, point of hips and peak of feet; center of gravity of body is further away from the axis of rotation, and position of hang under is achieved with a greater angle in shoulder joint, and smaller in the hip joint; phase of front swing in hang under is realized with higher extension speed in hip joint and with expressed anti – flexion in the shoulder joint. All the above stated contributes to leave bars much later and again reach for with stretched arms, and thus there were no errors in the execution. Obtained information about the differences in performing between top gymnast and middle class gymnast have contributed to the identification of technical errors during execution and represents very important step in detection and elimination of them, generally in artistic gymnastic, not only for the specified element.

Keywords: *artistic gymnastics, kinematic analysis, identification, technical errors.*

INTRODUCTION

Researches in the field of kinematic analysis of a certain kind of movement are becoming more and more frequent in artistic gymnastics; particularly as the obtained information enables more rational and economical instruction and acquisition of the analyzed movement (Brueggmann, Cheetam & Arampatzis, 1994; Takei, 1998; Yeadon & Brewin, 2003; Hiley & Yeadon, 2007; Heng, 2007; Hanin & Hanina 2009, etc).

The apparatus which offers all competitors equal possibility of achieving top results is parallel bars. Success on this apparatus largely depends on knowing all the details of complex technique elements, therefore many research papers are focused on this feature. However, very few research papers deals with kinematic analysis of the parallel bars elements. Linge, Hallingstad and Solberg (2006) dealt with the modeling of the parallel bars in Men's Artistic Gymnastics. Prassas & Ariel (2005) dealt with the kinematics of giant swings and (Prassas, 1994) back toss on the parallel bars, as well as Tsuchiya, Murata, Fukunaga (2004) who dealt with the kinetic analysis of the same element. The double back salto dismount from the parallel bars was researched by Gervais & Dunn (2003). Additionally, there were many research papers which dealt with the comparative study of two similar elements. Kolar E., Kolar K. A., & Stuhec (2001) conducted comparative analysis of selected biomechanic characteristics between a support backward swing and support swing for the 1 1/4 straddle-piked forward salto on the parallel bars. Furthermore, there are research papers which concentrate on the examining of the new elements. A detailed study of this kind was carried out by Cuk (1996), with the aim of determining the procedure used to prepare a new exercise, from the initial idea to its realization.

Basket to handstand on Parallel Bars (Figure 1) belongs to the category of difficult elements which are very interesting for further research.

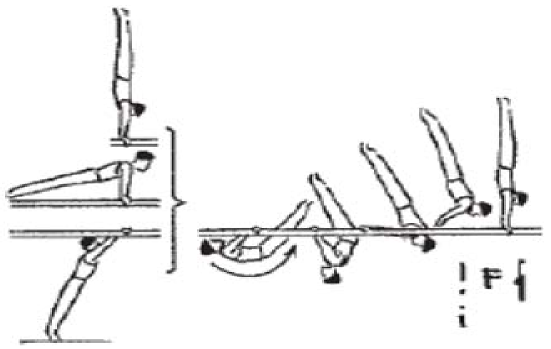

Figure 1. Basket to handstand on Parallel Bars (FIG, 2013).

This is the element which can be classified as an element belonging to "D" difficulty group, and which, by its specific aspect, belongs to IV group of elements on parallel bars (underswings). The above named element has become so popular that it's performed in all European and World championship finals, as well as in the Olympic Games. There is no top competitor on parallel bars who does not perform basket to handstand as integral part of his exercise. The reason of high popularity of basket to handstand is not only obtaining points for difficulty (difficulty values – D score – 0.40 points) and fulfilling a specific requirement (element groups – underswings – 0.50 points). The other important reason is that this element is highly perspective, since it has the possibility of advancing into more complex elements in the same structure group (Basket with 1/2 and 1/1 turn to handstand, Basket with immed. straddle cut to support, Basket with inlocation – el grip and hop to handstand – Cucherat, Basket to one rail handstand – Chiarlo).

The technique shown in the Code of Points (FIG, 2013) closely resembles to backward clear circle to handstand as performed on the high bar (Figure 1). During this technique, the gymnast maintains the hip flexion angle throughout most of the circle, in particular while he is below the bars (Figure 1). It has been recommended that this technique is used during the initial stages of learning the felge (Davis, 2005), probably because it is less demanding for the young gymnasts. However, the technique used by many senior gymnasts more closely resembles a "stoop stalder" (Davis, 2005). As the gymnast passes beneath the bars, a deep pike position (large hip flexion angle) is adopted, from which he rapidly extends passing through release and into the final handstand position.

The aim of this research is to establish a method of identifying technical errors in gymnastics at the example of basket from handstand to handstand. Research should find in which phases and kinematic parameters is reflected difference between the two groups of attempt basket to handstand, different in final performance and determine the phase and kinematic parameters that differentiate attempts without technical errors and attempts with great technical fault basket to handstand.

METHODS

The sample consisted of two athletes with different success on parallel bars: top and average gymnast. Top gymnast is the Slovenian national team member, a multiple medal winner at the parallel bars at World and European championships since 2000, as well as a multiple winner of the World Cup on the same apparatus. In all official competitions since 2001 till today, competitor, in his competitive part of exercises on the parallel bars, successfully performed the exercise with the help of which leads to the identification of technical errors - basket to handstand. The average gymnast is Serbian national team member in artistic gymnastics, champion of Serbia on parallel bars, but has no significant results in international competitions on this apparatus. In 2010 competitor has started training analyzed exercise, but due to large technical errors in execution is not yet included in his exercise on parallel bars. Both gymnasts have similar morphological characteristics (Table 1):

Table 1
Morphological characteristics of gymnasts.

Longitudinal dimension	*Top gymnast*	*Average gymnast*
Body height	*1.65 m*	*1.64 m*
Head	*0.21 m*	*0.22 m*
Trunk	*0.59 m*	*0.61 m*
Legs + foot	*1.09 m*	*1.08 m*
Hand	*0.54 m*	*0.56 m*
Transversal dimensions		
Width of hips	*0.31 m*	*0.29 m*
Shoulder width	*0.45 m*	*0.43 m*
Body weight	*63 kg*	*63 kg*

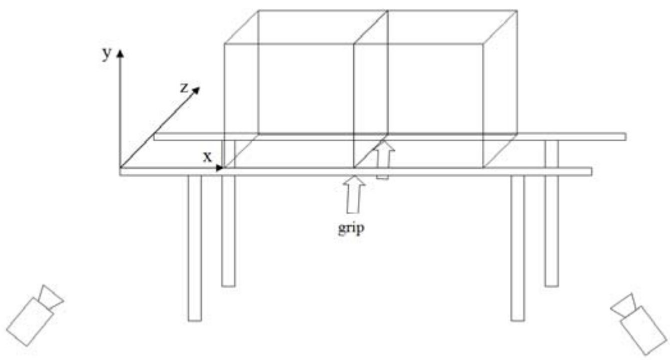

Figure 2. Space calibration.

Gymnasts performed basket to handstand at the training. All attempts were recorded with the help of two synchronized cameras DVCAM - Sony - □ SR - 300 PK, with a frequency of 50 Hz. Before recording, and for precise space calibration, two reference frames were videotaped ($1m^3$), which were positioned in the middle of the Parallel bars (Figure 2).

For research purposes, there were ten attempts rated as successful (without technical errors) performed by the top gymnasts and ten rated as unsuccessful attempts (with a large error) executed by the average gymnast. Criteria for successful and unsuccessful execution were assessments of three brevet judges.

In order to determine the kinematic parameters and represent kinograms, Ariel Performance 3D video system was used for kinematic analysis (APAS). As part of the kinematic analysis, digitization of the 15 – segment model of competitors was conducted. As a performed element had features of a two-dimensional motion, there was no significant movement along the "z" axis.

For the purpose of the research, the positions and trajectories of the referential points on the “x” and “y” axes were analyzed (the body centre of gravity, TXBCG, TYBCG), the velocity of the referential points (the body centre of gravity – VEBCG, the tip of the right foot VEFOO, the centre of the right shoulder joint – VESHO and the centre of the right hip joint – VEHIP), the goniometric characteristics: the angle (the right hip joint – ANHIP, the right shoulder joint – ANSHO, the trunk and x-axis – ANTUX, the legs and x-axis – ANLEX) and the angular velocity (the right hip joint – AVHIP, the right shoulder joint – AVSHO).

For the purposes of this research, with expert analysis form research of Velickovic et all. (2011), for each phase were selected following time sequence:

a) Phase one: 0.12s, 0.26s, 0.36s, 0.44s,
b) Phase two: 0.56s, 0.66s, 0.78s, 0.84s, 0.86s, 0.92s, 1.02s, 1.08s, 1.16s,
c) Phase three: 1.30s, 1.36s, 1.38s, 1.44s, 1.52s,
d) Phase four: 1.54s, 1.58s, 1.64s, 1.72s, 1.84s.

With the intention to better and more accurately describe the movement, selected were four to five positions – time sequences (for a second phase nine), with the aim to cover beginning, middle and completion of phase. In phases where movement was slower was selected fewer positions – sequences, and in phases where movement was faster was selected more positions (Velickovic et all, 2011).

The value of one parameter in one sequence of all distinguished efforts represents one variable, and the encoding is as follows in table 2.

Table 2
The value of one parameter in one sequence of all distinguished efforts represents one variable, and the encoding.

The first two letters represent the parameter	The next three letters represent a point, segment or joint	The numbers at the end of the code indicate the time sequence
TX – trajectories on the x axis TY – trajectories on the y axis VE – velocity AN – the angle AV – the angular velocity	BCG – the body centre of gravity FOO – the foot HIP – the hip SHO – the shoulder ANHIP – hip joint ANSHO – shoulder joint TUX – trunk in relation to the x-axis LEX – legs in relation to the x-axis	012 – 0,12s . . 102 – 1,02s

Example: AVSHO012 – the angular velocity shoulder in 0.12 sec.

The obtained parameters of motion (kinematic and goniometric characteristics) were further analyzed using descriptive and comparative statistics, measures of central tendency and dispersion of results: Mean – MEAN, standard deviation – STD, standard error of the mean – STD ERROR.

T – test for independent samples – was applied to determine the mean differences of analyzed kinematic parameters (significant positions) between 10 attempts of top and 10 attempts of average gymnast. Statistical analysis was performed by software package SPSS v 20 for Windows.

RESULTS

The values of the arithmetic means between 10 attempts of all analyzed parameters of movement for all the observed time sequences are shown in graphs.

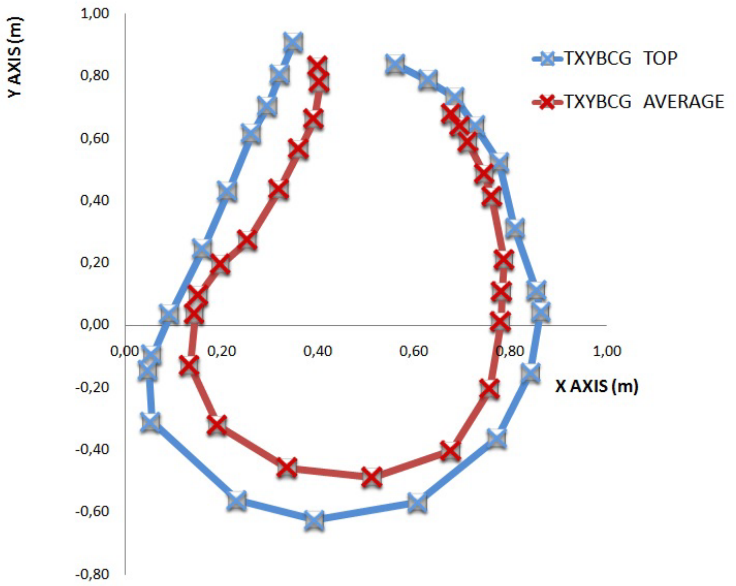

Figure 3. Trajectory of the center of gravity of the body in the "xy" axis – means.

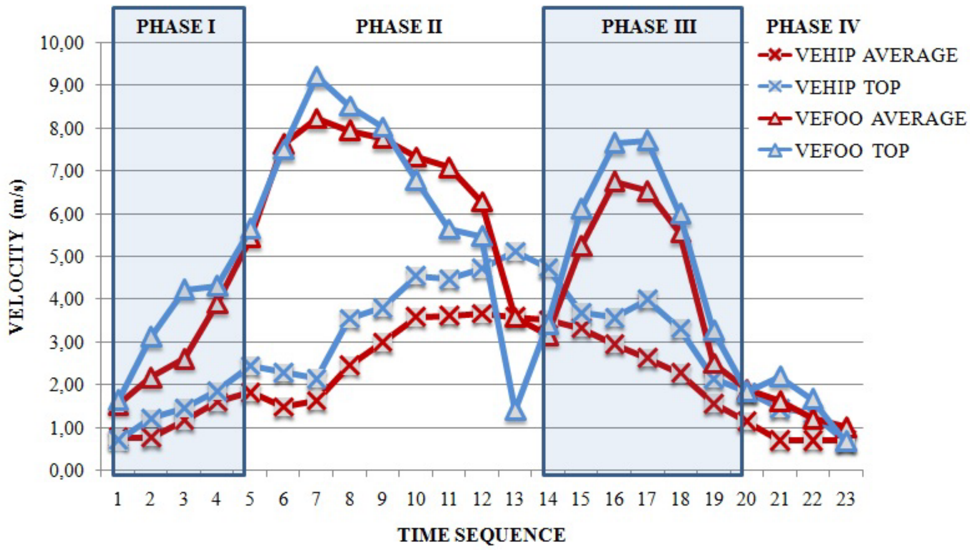

Figure 4. The velocity of the hips and feet – means.

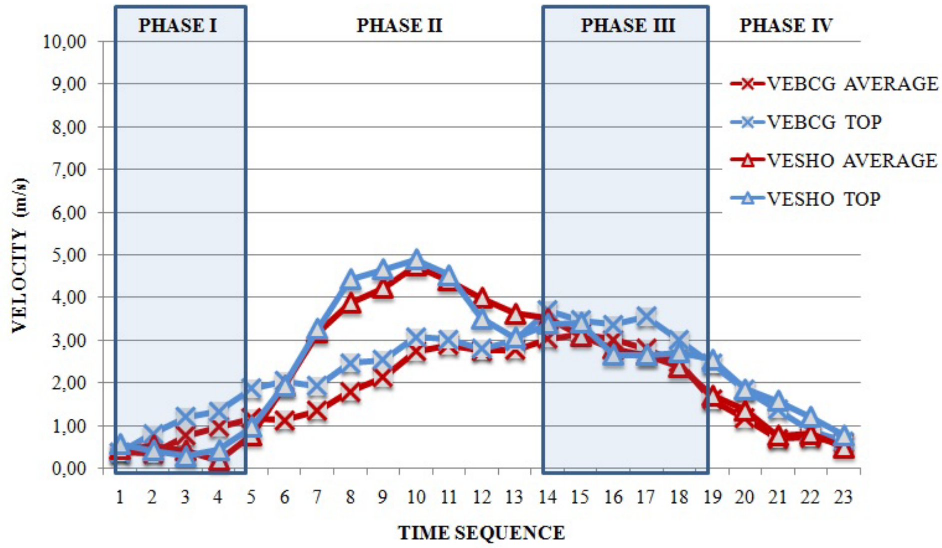

Figure 5. Velocity of gravity of the body and shoulders – means.

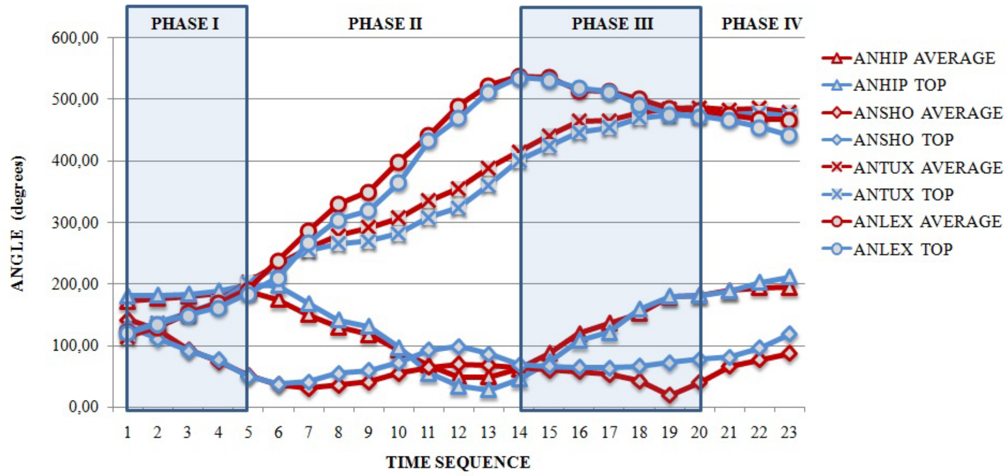

Figure 6. Referent angles – means.

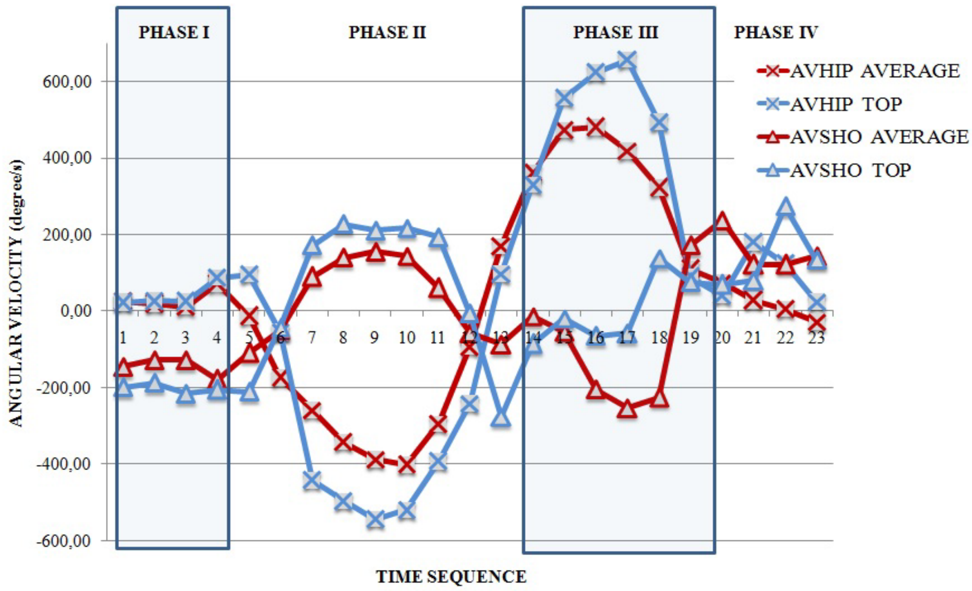

Figure 7. Angular velocities in referent angles – means.

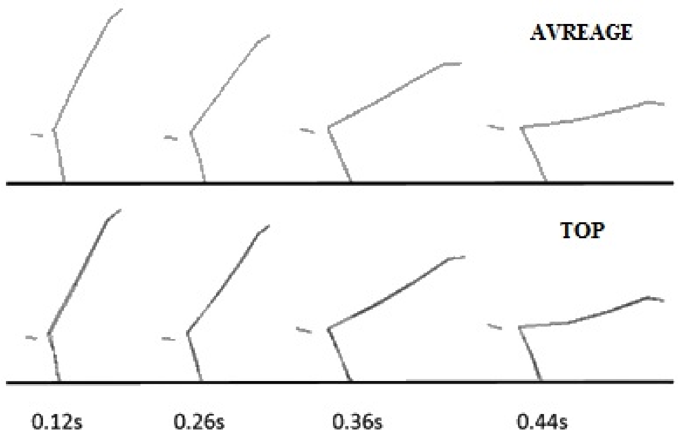

Figure 8. Phase one basket to handstand.

Table 3
Statistical significance of the T – test between successful and unsuccessful attempts – Phase I.

		PARAMETERS – PHASE I											
		TXBCG	TYBCG	VEBCG	VESHO	VEHIP	VEFOO	AVSHO	ANTUX	ANHIP	ANLEX	AVSHO	AVHIP
TIME SEQUENCES	2	(.00	0.00	0.29	0.20	0.59	0.14	0.19	0.09	0.08	0.00	0.99	0.41
	4	(.00	0.00	0.00	0.06	0.00	0.00	0.07	0.00	0.00	0.02	0.02	0.47
	6	(.00	0.00	0.00	0.18	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.61
	4	(.00	0.00	0.00	0.09	0.00	0.00	0.06	0.01	0.00	0.00	0.00	0.74

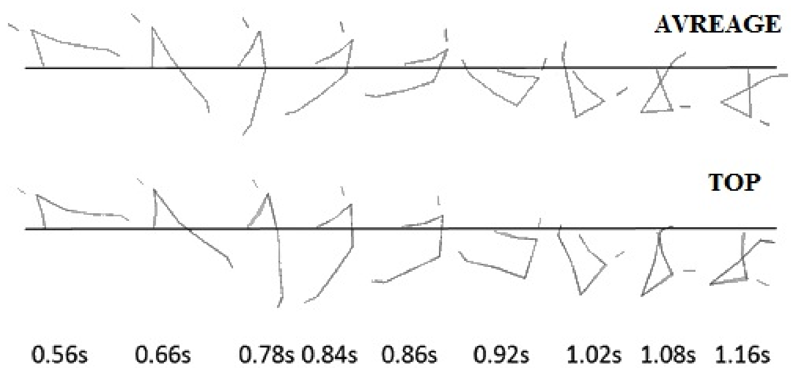

Figure 9. Second phase basket to handstand.

The first phase is shown on Figure 8. By visual inspection of image, differences in the shown sequences are not visible.

Reviewing figures 3 – 7 and table 2 reveals the following:

a) Trajectory of the center of body gravity has a slightly higher trajectory and is nearer to the center of rotation at the top gymnast (Figure 8 – Phase I), statistically significant (TXBCG and TYBCG – Table 2);

b) The top of the feet, hips and body center of gravity at top gymnast achieved greater speed (Figures 4 and 5), significantly in the last three time sequences (VEFOO, VEHIP, VEBCG – Table 1). Point of shoulders almost equally slow down with both gymnasts and the differences were not statistically significant (VESHO – Table 3);

c) Differences in the shoulder joint angles are about 4^{O} and not statistically significant (Figure 6), but the angular velocity of retro flexion (Figure 7) have significantly higher values with top gymnast (AVSHO – Table 3). The angle of the hip joint (ANHIP), as well as the position of the trunk and legs in relation to the x-axis (ANTUX, ANLEX) have significantly higher values at top gymnasts (greater hyperextension - Table 3). The angular velocity of extension in this joint (ANHIP) is close to zero values with both gymnasts and have no statistically significant differences.

By visual examination of Figure 9 we can observe that a top gymnast, after losing balanced position (ts from 0.78s to 1.02s), is significantly moving away from the axis of rotation (higher angle in the shoulder joint, the hip point is more moved back). Also, at the end of the fall (ts 1.24s), top gymnast achieves greater flexion in the hip joint.

Review of the figures 3 – 7 and table 3 notes next:

a) Body center of gravity is moving on wider path with top gymnast (forming larger semicircle – Figure 4) during the whole second phase (mostly significant - Table 3);

b) Body center of gravity and hip point achieves greater velocity with top gymnast during whole second phase. All values are statistically significant (Table 4), and the difference between speed of BCG ranges from 0.1 to 0.7 m/s and hip velocity from 0.4 to 1.4 m/s in favor of top gymnast. Foot peak velocity has higher values until the point of entry into antigravity phase (ts 0.78s), after which these values are higher with the average gymnast. The velocity of the shoulder after leaving the support surface (ts 0.66 s) is higher with the top gymnast. After descending of this point below the bars (after ts 1.02) speed has greater values with the average gymnast;

c) The angle of the shoulder joint (Figure 6) and move of ante flexion is much more pronounced and consistently has larger values with top gymnast. These values are statistically significant from the moment of exit point of the shoulder from support surface (loss of balance) to the beginning of ante flexion in the shoulder joint. Movement of ante flexion lasts until descent of the shoulder point below the bars (ts 1.08s). From this time sequence finds the movement of retro flexion, which is also significantly faster with the top gymnast. At the end of this phase angle of the shoulder joint is significantly higher with the top gymnast.

d) Observing the hip joint, there is a pronounced *"kurbet"* (rapid hyperextension in order to achieve faster flexion that follows the further movement) was ascertained in a time sequence from 0.56 to 0.66s. In the first part of the second phase angle of the hip joint is higher with top gymnast. The descent of shoulder point below the bars (ts 1.02s) begins with much higher angular velocity of flexion in the joint (Figure 7) and the achievement of significantly higher flexion (Figure 6) with the top gymnast. A top gymnast achieves significantly greater flexion in the hip joint as it passes through the lower vertical (ts 1.24s). Flexion is approximately 30^{O} compared to the approximate 55^{O} with average gymnast. Trunk and legs throughout this phase squint smaller angle with the x axis with top gymnast.

Table 4
The statistical significances of T – test – Phase II.

	PARAMETERS – PHASE II											
TIME SEQUENCES	TXBCG	TYBCG	VEBCG	VESHO	VEHIP	VEFOO	AVSHO	ANTUX	ANHIP	ANLEX	AVSHO	AVHIP
56	0.00	0.60	0.00	0.71	0.00	0.00	0.73	0.02	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.45	0.00	0.36	0.13	0.83	0.00	0.00	0.00	0.10
78	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.63	0.00	0.00	0.00
92	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00
102	0.33	0.00	0.03	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02
108	0.61	0.00	0.04	0.03	0.00	0.86	0.00	0.00	0.00	0.00	0.09	0.00
116	0.22	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.40
124	0.35	0.30	0.00	0.95	0.00	0.67	0.27	0.00	0.00	0.07	0.01	0.00

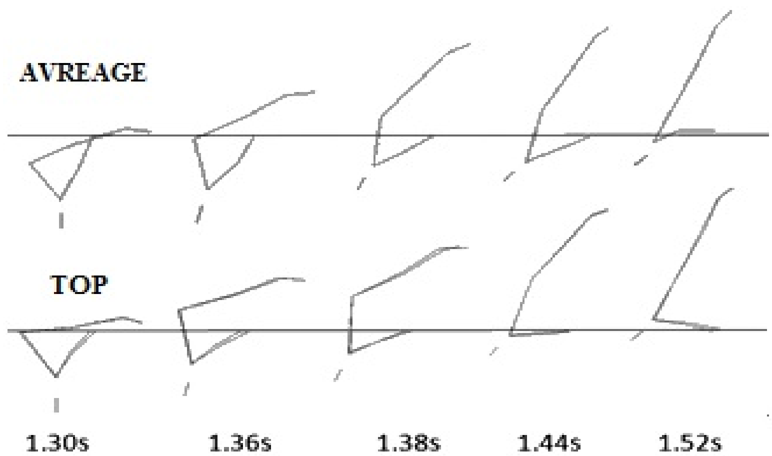

Figure 10. Third phase basket to handstand.

Visual inspection of Figure 10 shows that the average gymnast reaches the full extension of the hip joint much earlier and leaves the bars much earlier (ts 1.52s shoulders are below the bars).Review of the figures 3 – 7 and table 4 notes next:

a) BCG trajectory still has a wider path with top gymnast. Mentioned differences were not statistically significant, except the TYBCG in the last two sequences, when the height of the BCG has larger values with the top gymnast;

b) The values of velocities of all the reference points are higher with top gymnast, mostly statistically significant (except for the point of the shoulder);

c) After entering the third phase angle of the shoulder joint continues to move at an accelerated retro flexion with average gymnast almost to the end of phase. The value of the angle is reduced to 20^{O}. At this stage ante flexion in the mentioned joint is not recorded. With the top gymnast the reverse mode of the shoulder joint reveals – a movement of accelerated ante flexion. Mentioned differences are mostly statistically significant (Table 5);

d) The angle of the hip joint has similar trend with both gymnasts – accelerated extension, just as this action is much more prominent with the top gymnast (statistically significant);

e) The angle of the trunk in relation to the x-axis still has significantly smaller values with the top gymnast.

Table 5
The statistical significances of T – test – Phase III.

	PARAMETERS – PHASE III											
TIME SEQUENCES	TXBCG	TYBCG	VEBCG	VESHO	VEHIP	VEFOO	AVSHO	ANTUX	ANHIP	ANLEX	AVSHO	AVHIP
30	.44	.15	.00	.02	.00	.04	.98	.00	.00	.31	.01	.00
36	.77	.70	.00	.48	.00	.00	.02	.00	.00	.13	.00	.00
38	.77	.14	.00	.76	.00	.00	.00	.00	.00	.04	.00	.00
44	.13	.00	.00	.15	.00	.00	.00	.03	.61	.61	.00	.00
52	.06	.01	.00	.00	.00	.00	.00	.00	.66	.31	.28	.07

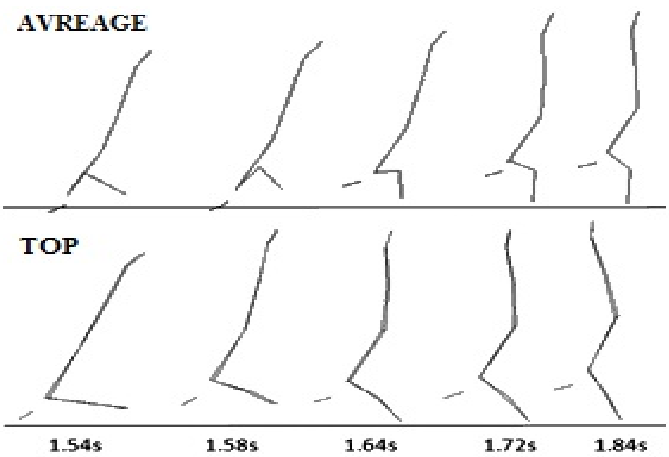

Figure 11. Fourth phase basket to handstand.

Viewing figure 11, with the average gymnast can be seen distinct convulsion of hands after leaving the bars, and at reaching bars at lower height with bent arms.

Review of the figures 3 – 7 and table 6 notes next:

a) Significantly higher and further path (relative to the grip) BCG with the top gymnast;

b) Speed of reference points, especially in without support phase (significantly) higher for the top gymnast;

c) The angle of the shoulder joint has consistently larger values with the top gymnast. With the average gymnast at the beginning of the phase without support registers retroflexion with the elbow joint bent very much, in order to begin anteflexion of shoulder and extension of the elbow joint when the gymnast reaches the bars;

d) A statistically significant extension in the hip joint at the end of the movement in favor of larger values with the top gymnast.

Table 5
The statistical significances of T – test – Phase IV.

	PARAMETERS – PHASE IV											
TIME SEQUENCES	TXBCG	TYBCG	VEBCG	VESHO	VEHIP	VEFOO	AVSHO	ANTUX	ANHIP	ANLEX	AVSHO	AVHIP
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.47	0.20	0.00	0.89
64	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.03	0.32	0.22	0.20	0.00
72	0.00	0.00	0.23	0.00	0.00	0.00	0.01	0.05	0.00	0.01	0.06	0.00
84	0.00	0.00	0.10	0.28	0.20	0.01	0.00	0.10	0.00	0.00	0.80	0.77

DISCUSSION

The first phase of the movement is characterized by significantly faster drop of the top gymnast, concluded on the basis of the speed of the center of gravity points of the body, hip and foot peaks and the angular velocity of retroflexion in the shoulder joint. Also the position for performing of the so-called „*kurbet*“ in the stage of fall is much better because statistically significant greater hyperextension in the hip joint was indentified.

In phase II drop with top gymnast continues faster, which was concluded on the basis of speed point of BCG, hip and shoulder. Balanced position is faster lost and BCG moves away from the axis of rotation, which is aided by the more pronounced „*kurbet*“ performed while the gymnast is still in support phase.

Entering the antigravity phase values of velocity point BCG, hip and shoulders are falling due to the effects of gravity, but they still have larger values with top gymnast.

The reason lies in better preconditions with top gymnast. The lower level of kinetic energy, forces to leave the bars in the final amplitude of the pendulum, which is below the level of reaching the bars by the point of the shoulder. Unlike the previous, top gymnast, amplitude of the pendulum and level of kinetic energy, increases with effective operations in previous phase (already mentioned), then with accelerated extension in hip joint (during the entire Phase III) and with accelerated anteflexion in the shoulder joint.

How will the IV phase be performed, whether with thrust on bent or stretched arms towards the handstand, depends on the preconditions acquired in the previous phases which has already been mentioned.

A top gymnast acts stronger and on longer path, achieves greater kinetic energy with the effect, primarily of external forces in phase II and internal forces in the III phase, so that the result is much higher trajectory of the center of body gravity in unsupport phase (IV). The re-grip of bars will be in a much higher position, which allows to perform actual movement without error, without delay, and on stretched arms. The evaluation of the movement is done only in the fourth phase, when we can conclude errors such as bent arms and pronounced delay in completion of the movement. Exactly this is noted with the average gymnast – leaving the bars with extremely bent arms, and re-griping bars in the lower position of BCG with extremely bent arms.

CONCLUSION

Determining the cause of bad performance, is significantly easier way in the planning and programming process of removing the errors and working on further improvement of the analyzed movement. With method of identification we can significantly contribute not only in elimination of technical errors, but also to more successful training of new elements, and can be applied to a large number of elements in artistic gymnastic. This would significantly reduce the number of errors in the training of new elements when the gymnast is still in the phase of wide irradiation and generalizations, and later would be, if there is a need, much easier to identify and eliminate technical errors during the execution.

In future researches could be done an analysis of the variability of kinematic parameters of different performing styles of basket to handstand. It could also be conducted research which would determine the difference in the amount of produced energy between successful and unsuccessful execution and execution between average and top gymnasts for the mentioned element. By this researches we could reach the kinematic parameters wich represent the ideal performance technique of basket to handstand.

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