UDC: 796.417.071.2-055.2
Professional paper

THE DIFFERENCE BETWEEN THE MAIN KINEMATIC INDICATORS OF BACKWARD SOMERSAULT AND FRONT SOMERSAULT OF AN ELITE ATHLETE

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Abstract

The main purpose of this study was to compare the main kinematic indicators between two technical elements of acrobatics: back somersault and front somersault performed by an elite gymnast. After shooting with three digital cameras (60Hz/s) and calibrating the position where the movement with the frame is performed (200cmx200cmx200cm), the shot material is processed according to the process of modules of the Kinetic Analysis System APAS (Ariel Performance Analysis System). The model created for the gymnast's body consists of 18 points. The results show that the anteroposterior-forward displacement of the center of gravity of the body of the gymnast (CG) during the flight phase of the forward somersault is 164 cm, which compared to the front somersault (141cm), is larger by 23 cm. But, the displacement of the CG to the somersault forward in the vertical-upward direction up to the highest point is 45 cm, which compared to the somersault backwards (66 cm), is lower by 21 cm. Salto forward from the start of the push up to the fall is performed for a time of about 0.86 s, which means that compared to the duration of the realization of the somersault backwards (0.96 s), is done for a shorter time of 0.1 s. During the push phase of the back somersault the value of the maximum velocity of the CG in the vertical-upward direction is 3.18 m/s which in contrast to the forward somersault this value is significantly smaller (2.65m / s). The maximum velocity of the hands in the vertical-upward direction of the back somersault is 8.72 m / s, while in the front somersaults the velocity of the hands is almost the same as that of the backward somersaults, but in the anteroposterior-forward direction and the value of it is 8.2 m/s. This difference in the analyzed kinematic indicators probably depends on the velocity of the momentum, the take of phase of the direction, the rush of the hands and its direction, the structure of the movement, etc.

Keywords: Backward somersault, forward somersault, kinematic analysis

1. Introduction

Backward somersault and forward somersault are important acrobatic elements. They are part of the group of dynamic acrobatic exercises with direction of movement back and forth. According to the degree of difficulty they belong to the group of exercises with one axis of rotation. The technical basis of these acrobatic elements is the rotational movement of the body back and forth, which is achieved by energetically pushing the legs off the ground and gathering the body by bringing the knees in front of the face. They are executed from the place and with rush. In the

acrobatic series, it is often preceded by another element, such as: Round off, forward roll, reverse rotation or another somersault. In the compositions for pioneers and juniors the Backward somersault and forward somersault are almost the main elements, while in the compositions of the highest-level gymnasts they are an integral part of each composition either as preliminary connecting elements for the other elements, or as main elements. Today, within the Olympic ranking, the gymnastic carpet as the discipline of multi-sport gymnastics in women is ranked fourth while in men the first. There are differences in compositions for men and women.
In women, the exercises are accompanied by music and the composition lasts from 70-90 seconds, the composition also contains elements of rhythmic gymnastics. While in men 50-70 seconds.
There are already a solid number of studies from the kinematic analysis of gymnastic elements such as somersaults back and forth. During these analyzes, the values of the numerous biomechanical characteristics necessary for the efficient performance of the elements in question were determined (Payne and Barker 1976, Bruggemann 1981, Hong and Bruggemann 1992, Knoll 1992, Newton et al., 1992, McNitt-Gray et al., 1994). Angsuman Banerjee has determined the angular velocity of the body during the back jumping phase (13.25 rad / s). A similar result was obtained by Chen et al. (2009); Brüeggemann (1983, 1994); Geiblinger et al. (1995); Hwang et al. (1990); Knoll (1992); Knoll and Krug (1990); Mkaouer et al. (2012); Sadowski et al. (2005). The aforementioned authors for the key components of the somersault performed after turning sideways with flip-flop, agree that velocities of 5 to 6 m / s and a break with an angle between 75 and 85 ° are optimal for performing somersaults lying down. Al-Beshlawi (2010), in his study with the elite gymnasts of Egypt confirmed that the total time of realization of the element is 0.92 to 1.04 sec. Where the three phases of the element are involved: the propulsion phase (0.11 sec.), the flight phase (0.55 sec.) and the fall phase (0.26 sec.).

2. The purpose of the study

The main purpose of this study was to compare the main kinematic indicators between two acrobatic elements: Backward somersault and forward somersault performed by an elite gymnast. From the kinematic indicators of the position of the body of the gymnast, the trajectories of the movement of the center of gravity of the body of the gymnast (CG) and the displacements in all three directions of the three-dimensional system (X, Y, Z) were analyzed. The values of maximum velocity during the take off phase and the landing phase of the gymnast's CG were also analyzed for both techniques in question, the maximum velocity of the hands and the time for all three phases of the techniques.

3. Methods

3.1 *Analyzed subject and work procedure*: The performance of backward somersault and forward somersault is performed by a gymnast with many years of experience and high success of the competition from the Republic of Kosovo (D.K.), with a body height of 168 cm and a body mass of 54 kg. Her engagement during the performance is maximal and for analysis is taken her most successful attempt for both acrobatic elements. The shooting of the techniques was done in a gymnastic floor with proper environment conditions with three digital cameras (60Hz / s), located at an angle of about 120 degrees from each other.. The distance of the cameras from the place of performance is about 6 meters. The cameras are fixed without being affected by floor vibration. At the place where the technique was to be performed, the calibration frame with

dimensions (200cmx200cmx200cm) was initially shot. Then the calibration frame is removed and in the same visual field the performance of the techniques begins.
The recorded material is processed according to the APAS System module process. After recording the material, the film is cut, limiting the images from the beginning of the push phase to the end of the fall to the floor. This footage was transferred to a computer hard drive for digitization. For the techniques in question after cutting the film is created the model of the lever system of the body of the gymnast consisting of 18 points of her body mainly in the joints of the body. After the recorded and synchronized images are cut for all three cameras, the digitization begins. In this study, manual digitization was performed under the control of the computer operator for previously synchronized video images for all cameras.
After the digitization, the image model was transformed from 2D to 3D. The signal (motion curve) is then filtered for each point analyzed on all three axes of the system. Filtering is used to remove small random digitization errors from the transformed image sequence. This module can improve shared digitized sites by minimizing the effect of mistakes made during the analysis process. At the end, the data obtained from the curves obtained for the displacements, velocity and duration of the technique are read.
3.2 Kinematically analyzed variabiles: After all the preliminary steps of the APAS system modules are performed, at the end from the Apas View module the values of the kinematic indicators are read, respectively the data are extracted from the respective curves for all the variables analyzed at a certain time. The variables analyzed in this study are: the trajectory of the movement of the center of gravity of the body of the gymnast (CG); values of maximum velocity during the propulsion phase, hand rush and landing; duration of performance for all three phases analyzed (take off, flight phaze and landing).
The trajectory of the gymnast's body movement (displacements) in all three directions of the three-dimensional system is described by the variables:

- Displacement of CG in mediolateral direction (left-right) - X axis,
- Displacement the CG in the anteroposterior direction (forward-backward) - Y axis,
- Displacement the CG in the vertical direction (up-down) - Z axis.

Maximum velocity values for crucial somersault moments:

- Maximum velocity in the vertical direction during the push phase.
- Maximum velocity in the vertical direction when landing to the floor.
- Maximum velocity of the hands in the vertical direction during the take off phase of the back somersault.
- Maximum velocity of the hands in the horizontal direction during the take off phase of the forward somersault.

Duration according the phases and the total time of realization of the technique.

- Duration of the take off phase at the backward somersault and forward somersault.
- Duration of the flight phase at the back jump and at the forward jump.
- Duration of the phase of landing to the back and front somersault.
- Duration during the flight phase from its beginning to the highest point of CG at the backward somersault and forward somersault.
- Duration during the flight phase from the highest point of the CG to the moment of touching the floor at the backward somersault and forward somersault.
- Total time at the backward somersault and forward somersault.

4. Results and discussion

After all the steps foreseen according to the modules of the Arial Performance Analysis System (APAS) have been developed, the necessary data for the important kinematic indicators on the trajectory of the movement of the center of gravity of the gymnast (displacements), have been obtained maximum velocity for certain moments and the time of realization of the technique according to the analyzed phases.

Table 1 shows the data for the back somersault: on the CG position, respectively the displacements in all three directions of the spatial system and the time of realization of the back-somersault according to the phases (take off, flight, 00and landing). During the take-off phase in the mediolateral direction the CG of the gymnast's body has almost no shift to the left or right.

In the anteroposterior direction during the takeoff phase the CG shifts to the direction of body movement (backwards) with a value of 17 cm. Meanwhile, a similar value of CG displacement is also in the vertical-upward direction of 15 cm (Fig. 1 a-contourogram). This phase is much shorter compared to the flight phase and lasts 0.06 seconds.

After the push (detachment) the flight phase of the gymnast's body begins during the back-somersault performance. Table 1 gives the values for the displacement of the CG from the start of the flight to its highest point, as well as the values from the highest point of the flight to the end of the flight phase. During the flight phase there is almost no displacement in the mediolateral direction. But it is understood in the anteroposterior-forward direction and in the vertical-upward direction the displacement is pronounced. From the start of the flight to its highest point, CG reaches a value of 75cm. Meanwhile from the highest point to the end of the flight phase CG in the anteroposterior direction (back) reaches a value of 66 cm. So, in total the displacement of the QR during the flight phase is 141 cm. During this phase the displacement of the CG in the vertical-upward direction to the highest point is 66 cm. The phase of the fall is touching the feet to the floor and cushioning the lowering of the body. The displacement of CG in the mediolateral direction is almost non-existent, but in the anteroposterior-back direction its value is 15 cm, while in the vertical-downward direction its value is 24 cm. At the end of the flight phase the gymnast landing to the floor with both feet and this drop (damping) phase lasts about 0.1 s.

Figure 1 (a) shows the back somersault contourogram with the center of gravity (CG) movement trajectory in the sagittal plane.The duration of the whole back somersault from the start of the take off to the landing is about 0.96 s. The total shift of CG in the mediolateral-left or right direction is almost non-existent. The displacement of the CG in the anteroposterior-backward direction is 173 cm, while in the vertical-upward direction the displacement value is about 81 cm.

Table 1. Displacement of the center of gravity of the gymnast's body in all three directions (X, Y, Z) during the three phases of the back somersault and the time of realization

	Take off	Flight		Landing
Displacement of CG (cm)	Start of take-off to end of take off	Start of flight to top of flight	Top of flight to end of flight	Start of landing to end of landing
X-mediolateral direction (cm)	1	1	1	1

Y-anteroposterior direction (cm)	17	75	66	15
Z – vertical direction (cm)	15	66	65	24
Time (s)	0,06	0,4	0,4	0,1
Time of phases (s)	0,06	0,8		0,1
Total time (s)	0,96			
X-mediolateral Total displacement	4			
Y-anteroposterior Total displacement	173			
Z-vertical Total displacement	81			

Data on the gymnast CG displacement and duration of the front somersault performance are given in Table 2. As during the backward somersault performance and during the forward somersault performance in the mediolateral direction the center of gravity of the body of the gymnast has no displacement to the left or to the right. But in the anteroposterior direction during the take-off phase the CG shifts in the direction of body movement (forward) and its value is 25 cm, which compared to the displacement value of the back somersault (17cm) of the forward somersault the displacement in this direction is bigger for 8 cm. Meanwhile, the displacement value of CG in the vertical-upward direction is 15 cm, which means that it is identical with the displacement value of the back somersault (Fig. 1, b-contourogram). The realization time of this phase is 0.08 s, which compared to the back somersault (0.06s) is slightly bigger.

In the same table (Table 2), the values for the displacement of the CG to the front somersault are reflected, from the beginning of the flight to its highest point, as well as the values from the highest point of the flight to the end of the phase of flight. During the flight phase the displacement in the mediolateral direction is small. In the anteroposterior-forward direction and in the vertical-upward direction the displacement is pronounced. From the start of the flight to its highest point CG reaches a value of 75cm. Meanwhile from the highest point to the end of the flight phase CG in the anteroposterior direction (after) reaches a value of 89 cm. So in total the forward displacement of the CG during the flight phase is 164 cm, which compared to the forward somersault (141cm), the displacement in this direction of the forward somersault is bigger by 23 cm. During this phase the displacement of the CG in the vertical-upward direction to the highest point is 45 cm, which compared to the back somersault (66 cm), is lower by 21 cm. While the CG displacement at the back somersault is bigger in the vertical-upward direction, at the forward somersault there is bigger displacement in the anteroposterior-forward direction. This difference depends on the velocity of the push, the phase of the push, the rush of the hands, etc. During the landing and amortization phase of the body descent, the displacement of the CG in the mediolateral direction is almost non-existent, but in the anteroposterior-forward direction its value is 15 cm, i.e. identical to the back somersault.

In the vertical-downward direction the value is 11 cm, smaller compared to the back somersault (24 cm) where this value is smaller by 13 cm. The duration of the landing (amortization) phase is about 0.06 s, slightly shorter compared to the front somersault (0.1 s).Figure 1 (b) shows the contourogram of the forward jump with the trajectory of the center of gravity (CG) movement in the sagittal plan. Forward somersault from the start of the take off to the landing is performed for a time of about 0.86 s, which means that compared to the duration of the realization of the backward somersault (0.96 s), is done for a shorter time of 0.1 s. The total shift of the CG in the mediolateral-left or right direction is very negligible. The displacement of the CG in the anteroposterior-forward direction is 204 cm, while in the vertical-upward direction the displacement value is 60 cm, so compared to the vertical-upward displacement of the back somersault (81 cm), the difference is 21 s.

These values of CG displacement of the gymnast's body show that in backward somersault bigger displacement is achieved in the vertical-upward direction by 21 cm, while in forward somersault bigger value of displacement of CG in comparison with backward somersault is achieved in the direction anteroposterior-forward with a difference of 31 cm (Fig. 2-Graph).

Table 2. Shifting the center of gravity of the gymnast's body (CG) in all three directions (X, Y, Z) during the three phases of the forward somersault and the time of realization

	Take off	Flight		Landing
Displacement of CG (cm)	Start of takeoff to end of take off	Start of flight to top of flight	Top of flight to end of flight	Start of landing to end of landing
X-mediolateral direction (cm)	1	7	5	1
Y-anteroposterior direction (cm)	25	75	89	15
Z – vertical direction (cm)	15	45	58	11
Time (s)	0,08	0,34	0,38	0,06
Time of phases (s)	0,08	0,72		0,06
Total time (s)	0,86			
X-mediolateral Total displacement	2			
Y-anteroposterior Total displacement	204			
Z-vertical Total displacement	60			

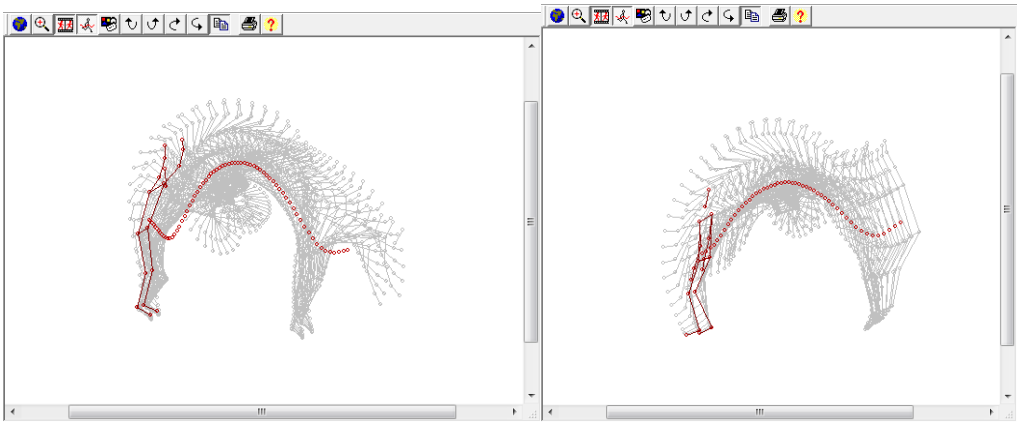

Figure 1. Contourograms: trajectory of the center of gravity (CG) of the gymnast in the sagittal plan (Subject D.K.): a) backward somersault; b) forward somersault

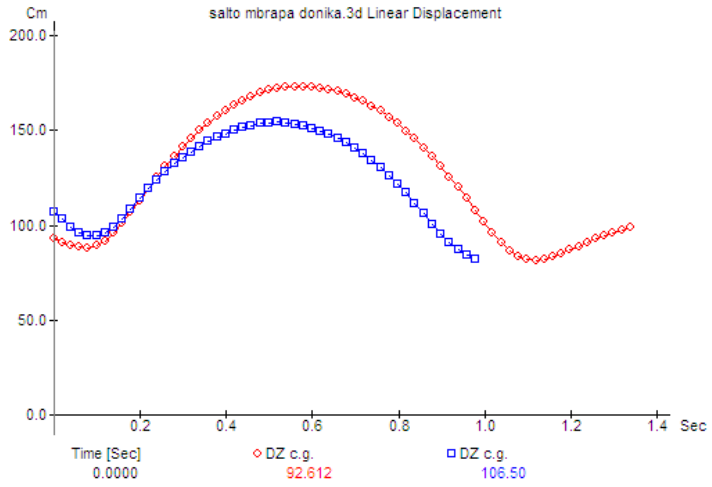

Figure 2. Graph. Trajectories of center of gravity (CG) movement in the sagittal plan (vertical axis) (red-somersault backward, blue-somersault forward)

Many performance characteristics of the somersault depend on the velocity of movement of the center of gravity at certain moments and the velocity of the rush of the hands. For example, the height of the CG in the flight phase and the movement of the body depend on the momentum, push and momentum of the hands.

Table 3 shows the data on the maximum CG velocity in the push phase, the drop phase, the rush of the hands and the time (percentages) when these maximum velocities occur for both the back and forward somersault.

The take-off phase is crucial to the success of the somersault. In the back somersault the value of the maximum velocity of the CG in the vertical-upward direction is 3.18 m / s and this occurs at 0.12 that before the total time (0.96s) or 12.5% of the back-somersault performance time, i.e. at the end of the propulsion phase. In contrast to the forward somersault the maximum CG

velocity in the vertical-upward direction is significantly lower (2.65m/s), whereas this occurs at 0.1 than before the total time (0.86s) or 11.6 % of performance time.

As mentioned above another factor of increasing the height of CG in the flight phase is also the rush of the hands. The push of the hands in the vertical-upward direction to the back somersault is 8.72 m/s and this occurs at the very beginning of the take-off phase, or at 0.02 than before the total time 0.96s) or 2% of the time of performance. In somersault forward the velocity of the hand rush is almost the same as that of somersault backwards, but not in the vertical-upward direction. In the front somersault the rush of the hands has greater velocity in the anteroposterior-forward direction and its value is 8.2 m/s. This occurs in the first 0.08 s of total time (0.66s) or 9% of performance time.

Since in the front somersault the rush of the hands has greater velocity in the anteroposterior-forward direction it certainly affects the shift with greater CG value in length, in contrast to the backward somersault. Conversely, at the rear somersault the maximum CG velocity has a bigger value in the vertical-upward direction, which should be among the factors of the highest CG elevation during the flight phase compared to the forward somersault. After the flight phase begins the last phase of the somersault or the landing of the body (touching the feet) to the floor. The rate of fall of CG in addition to the above factors is subject to the laws of physics on the free fall of bodies.

Since time is short and the body is in rotation, the efficiency of cushioning and body balance also depends on this rate of decline. The maximum velocity of CG in the vertical-down direction in the phase of landing back to the somersault is 3.01 m / s and this occurs at 0.9 s of somersault realization or 94% of the total performance time (0.96s).

Meanwhile, in the forward jump, the maximum velocity of QR in the vertical-downward direction is 2.74 m / s and this is achieved in 0.78 s of the realization of the forward somersault or 91% of the total performance time (0.86s). From the comparison of these values it can be seen that at the back somersault the maximum velocity of CG in the vertical-downward direction is higher compared to the forward somersault, as the maximum altitude of the CG in the flight phase is higher at the back somersault back somersault, in compliance with the law on the free fall of objects.

Table 3. Maximum velocity of the center of gravity of the gymnast during take off and landing, maximum velocity of the hands and the time when the maximum velocities are reached.

	Maximal velocity in take-off – vertical direction (m/s)	Time (percentage) when the maximum take-off velocity is reached of total time (s) (%)	Maximum wing velocity during pushing (m / s)	Time (percentage) when the maximum wing velocity is reached from the total time (s) (%)	Maximal velocity in landing – vertical direction (m/s)	Time (percentage) when the maximum release velocity is reached of total time (s) (%)
backward somersault	3,18 (m/s)	0,12(s)(12,5%) Tot time(0,96s)	8,72 (m/s) (downward)	0,02 (s)(2%) tot(0,96s)	3,01 (m/s)	0,9(s)(94%) tot(0,96s)
Forward somersault	2,65 (m/s)	0,1(s) (11,6%) Tot time(0,86s)	8,2 (m/s) (across)	0,08 (s) (9%) tot(0,86s)	2,74 (m/s)	0,78(s) (91%) tot(0,86s)

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