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THE KINEMATIC MODEL OF THE BASKET WITH ½ TURN TO HANDSTAND ON THE PARALLEL BARS

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Abstract. *The aim of this research is to perform a kinematic analysis of the basket with ½ turn to handstand on the parallel bars, so as to create the conditions for the successful creation of the teaching process and the process which would help perfect the abovementioned element. Mitja Petkovsek, a member of the Slovenian national team and one of the most successful competitors on the parallel bars in the last two Olympic cycles, was the one who successfully performed the swing to a handstand. The kinematic parameters were determined by using a 3-D video system for the APAS kinematic analysis and by using the Susanka body model (Čuk, 1996), which takes into consideration 17 points of reference and 15 segments. The research results have made it possible to define the kinematic exercise model, which requires a gravitational and anti-gravitational phase, as well as four sub-phases (upswing from a handstand, downswing to upswing, forward swing to upswing and a swing with a ½ turn around the vertical axis). A recommendation for the even more successful execution of the exercise analyzed here is the later execution of the post-active transfer of the swing from the feet to the body during the third sub-phase and the later release of one bar at the beginning of the fourth sub-phase.*

Key words: *kinematic analysis, expert analysis, parallel bars, Basket with ½ turn to handstand, gravitational phase, anti-gravitational phase*

1. INTRODUCTION

Nowadays it is quite obvious that the model of success in sports gymnastics has, as its basis, the most complex coordination elements, as well as their successful execution as part of the competitor's program. What also belongs to the group of the abovementioned elements is the "*basket with ½ turn to handstand*" (hereinto for BASKET 1/2T - Image 1). The reason why this exercise is so popular is that it can be upgraded into much more

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complex exercises (by adding another ½ turn), as well as the fact that it can be combined with other complex coordination exercises (D, E and super E difficulty) from the same or from other structure groups, thus enabling a gymnast to be awarded additional points and an increased starting grade for his program.

A rational and economical process of teaching and perfecting the BASKET 1/2T is possible only if the mentioned element is studied in detail, and especially if one gets to know those details which are not readily available to the visual inspection of the coach and the kinesthetic receptors of the gymnast who is exercising. The research which has been carried out to date has not provided us with enough reliable information which is necessary for the precise creation of a program for the technical preparation of this element. Information regarding the performance technique of this exercise is mostly based on a simple analysis of a video recording (Alekperov, 1976; Knirsch, 1983). Nevertheless, no detailed information regarding kinematic and dynamic structure, in the case of the BASKET 1/2T has been obtained to date.

Research which has as its aim the kinematic analysis of a certain kind of movement is becoming more and more frequent in sports gymnastics, precisely because the information that has been obtained enables a more rational and economical instruction and acquisition of the analyzed movement. Brüeggmann, Cheetam, Alp & Arampatzis (1994), using video material from the Olympic Games in Barcelona in1992, carried out research of the so-called "flying" exercises and dismounts on the horizontal bar. The analysis incorporated 70 exercises chosen from 10 different structure groups, and data was collected on all the competitors who actually performed those exercises at the aforementioned competition. The basic biomechanical parameters were calculated, which were used later on as the criterion for the optimization of the already familiar and the modeling of the new exercises. Kolar (1996) studied the execution techniques of the dismount from the horizontal bar, the double extended backward flip with a double spin around the vertical axis. The kinematic parameters of the analyzed exercise were determined by using the CMA system, and the dynamic parameters were determined by using an inverse mechanics procedure, and the IMGIM computer program. The exercise was split into the accumulation phase, the action phase and the realization phase. On the basis of the obtained results, the methodological process of training and perfecting the analyzed exercise was carried out. The procedure includes: preexisting knowledge of technique, specific physical preparations, a methodological procedure, help and preservation, the recognition and correction of errors. A detailed study of this kind was carried out by Čuk (1996), with the aim of determining the procedure used to prepare a new exercise, from the initial idea to its realization. The exercise used as the example was the "dismount with a clenched flip forward on the horizontal bar sideways". The procedure was carried out over seven phases, on a single subject, and included the analysis of 29 repetitions (15 with no technical errors and 14 with a technical error). The phases included the very idea for a new exercise, the creation of a hypothetical biomechanical model of movement, meeting the requirements of the International Gymnastics Federation, the creation of a basic methodological procedure, training and teaching the exercise, data collection by means of a (CMAS) kinematic analyzer and data analysis regarding the successful execution of the exercise, up to the final definition of the optimal biomechanical model and its inclusion in the database. For the purpose of analyzing the execution success of the exercise, two criteria were determined: the height of the body's center of gravity at the moment of the landing and the angle formed by the ground, feet and the center of gravity.

The 14 chosen variables significantly and to a great extent explained both criteria (92% of the variance of the height of the body's center of gravity and 88% of the angle during the landing). By means of a regressional analysis, the best predictors for the successful execution were identified.

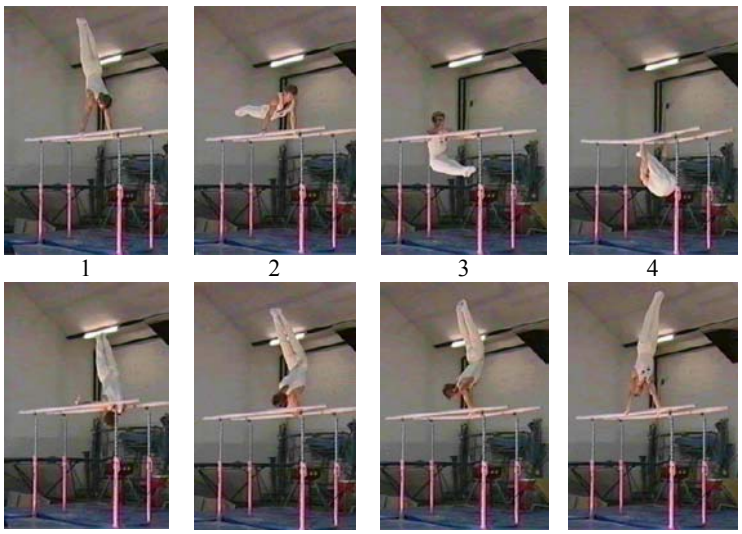


Fig 1. The Basket with ½ turn to handstand on the parallel bars

The aim of this paper is to perform a kinematic analysis and to determine the kinematic model of the "*basket with ½ turn to handstand on the parallel bars*" (Image 1), which creates the necessary preconditions for the successful execution of the technical preparation of this exercise.

2. THE METHOD

The kinematic analysis was performed on a single successful attempt at a BASKET 1/2T (without any visible technical and esthetic errors), which in the course of training, was performed by one of the most successful competitors on the parallel bars in the world, a member of the Slovenian national sports gymnastics team, Mitja Petkovšek (age 26 years, weight 63 kg, height 1.65 m). The video material was recorded in the "Narodni Dom" gymnastics hall in Ljubljana (Slovenia).

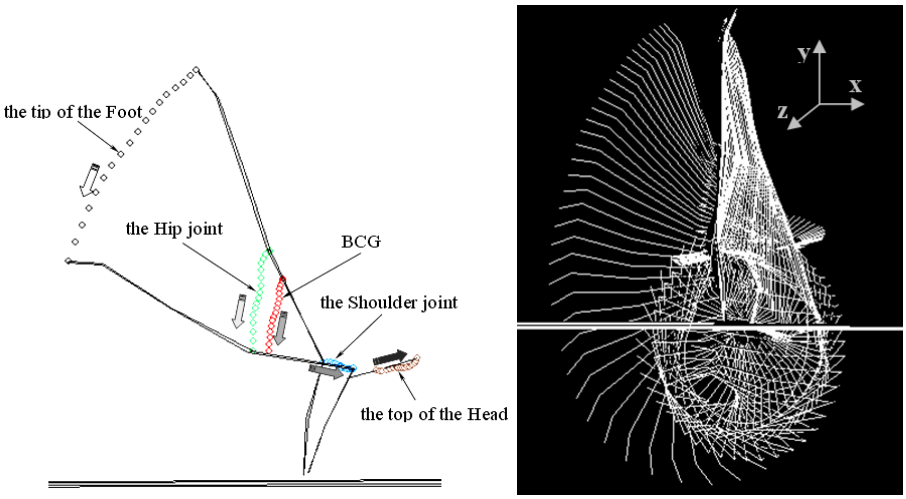
In order to determine the kinematic parameters and to present the kinogram, an Ariel Performance 3D video system was used for the kinematic analysis (Ariel, 2003). All the repetitions were recorded using two synchronized video DVCAM - SONY - ΔSR - 300 PK cameras, with a frequency of 50 Hz. Before the actual recording, and for the purpose of precise space calibration, two reference frames were recorded using the cameras ($1m^3$), which were positioned in the middle of the parallel bars. Since the referential frame defines the coordinate system orientation, which will be used in the data analysis, the order in which the points were read off the frame was done in such a manner that the "x" axis

matches the length of the poles, the "y" axis its height and the "z" axis the depth of the movement being analyzed, and the center of the coordinate system was at the beginning of the parallel bars (2m from the center of the support grip). As part of the kinematic analysis, a digitalization of the 15 segmented competitor model was carried out (Sušanka, 1987; taken from Čuk, 1996). For the requirements of this research, the ***positions and trajectories of the referential points on the "x", "y' and "z" axes*** were analyzed (the body's center of gravity, the tip of the right foot, the center of the right shoulder joint, the center of the left shoulder joint, the center of the right hip joint, the center of the left hip joint and the top of the head), then, ***the speed of the referential points*** (the body's center of gravity, the tip of the right foot, the center of the right shoulder joint, the center of the left shoulder joint, the center of the right hip joint, the center of the left hip join and top of the head), ***the goniometric characteristics:*** *the angle* (the right hip joint, the right shoulder joint, the left shoulder joint, the left and right elbow joint) and *the angular velocity* (the right hip joint, the right shoulder joint, the left shoulder joint, the left and right elbow joint).

3. RESULTS AND DISCUSSION

The research which has been carried out to date has not provided us with enough reliable information regarding the execution technique of this analyzed exercise.

The BASKET 1/2T kinogram on the "xy" plain, along with the body's center of gravity trajectory (Kinogram 1) encompassed a total of 115 positions, with a time interval of 0.02 seconds between each. The overall duration of the execution of the element was 2.4 seconds.



Kinogram 1. The Basket with ½ turn to handstand on the parallel bars

The trajectories of the referential points on the "xy" plain and the "z" axis are shown in Charts 1, 2 and 3. For the purpose of clearly presenting the results in Charts 2 and 3 the values of the "z" axis are shown on a reverse scale, so as to follow the "right hand rule", while choosing the directions of the coordinate axes.

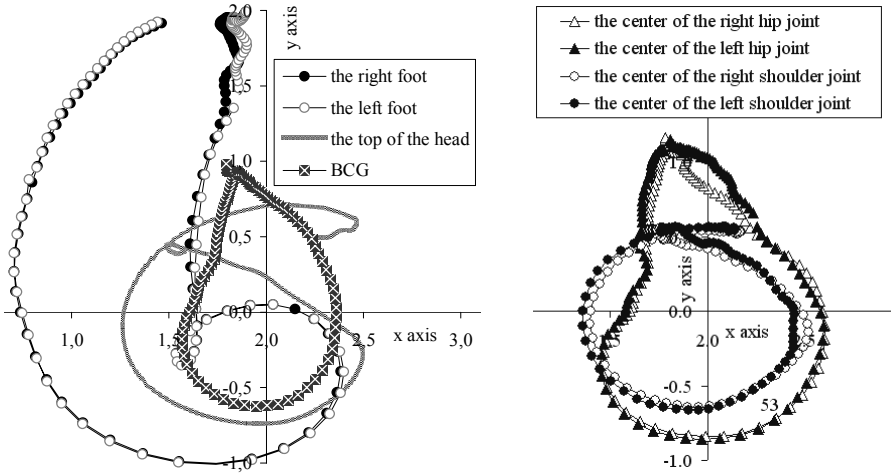


Chart 1. The trajectory of the points on the"xy" plain

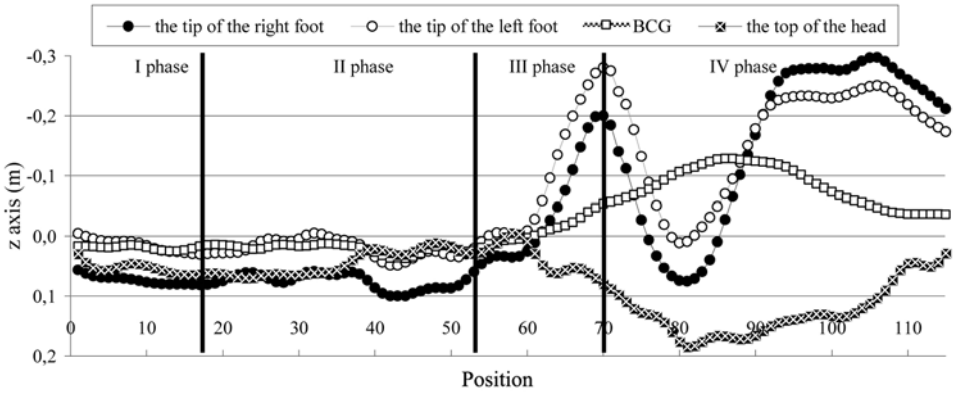


Chart 2. The trajectory of the tips of the feet, the body's center of gravity and the top of the head on the"z" axis

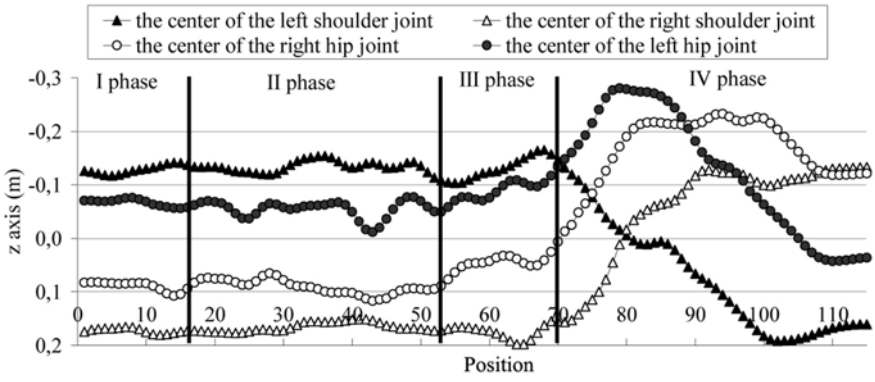


Chart 3. The trajectory of the shoulder joint and hip joint on the"z" axis

The values for the peripheral speed of the referential points, which are realized during the execution of the analyzed element, are shown in Chart 4, and in addition, the angular values of the angles between the referential segments of the body are shown in Chart 5, and the values of the angular velocities between the referential segments are shown in Chart 6. The negative values shown in Chart 6 represent a period of retroflexion in the shoulder joints and flexion in the hip joints, and the positive values represent a period of anteflexion in the shoulder joints and extension in the hip joints.

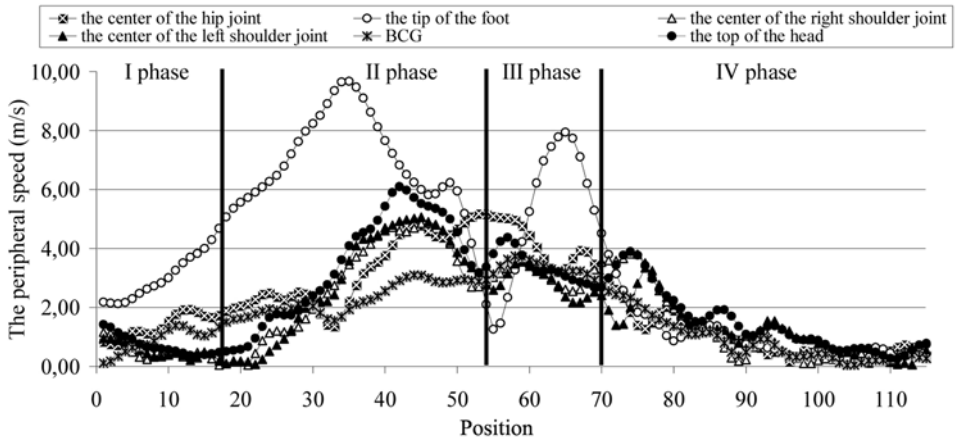


Chart 4. The peripheral speed of the referential points during the execution of the BASKET 1/2TT

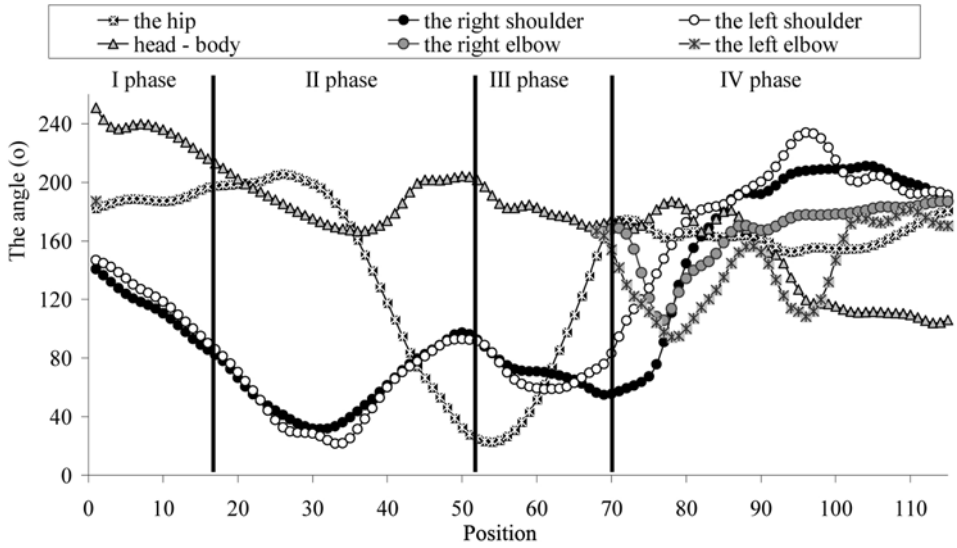


Chart 5. The angle of the referential segments during the execution of the BASKET 1/2T

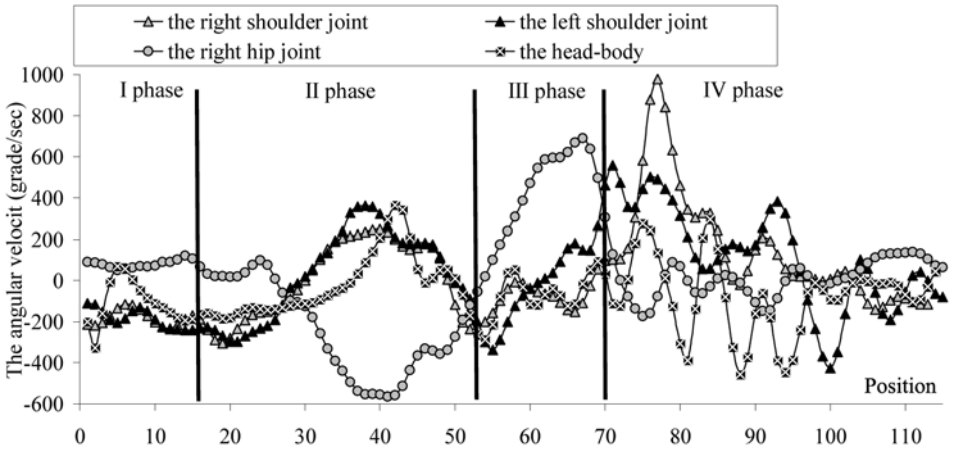


Chart 6. The angular velocity between the referential segments during the execution of the BASKET 1/2T

On the basis of the analysis of the kinematic parameters, two phases and four sub-phases were determined as part of the execution of this movement (a point already mentioned in the previous charts):

I - The gravitational phase (the movement takes place in the same direction as the gravitational pull)
- Sub-phase 1 - upswing from a handstand;
- Sub-phase 2 - downswing to upswing;

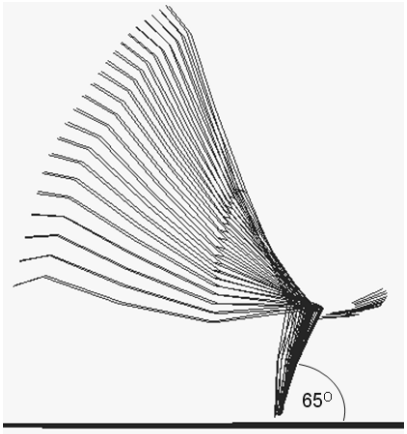
II - The anti-gravitational phase (the movement takes place in the direction opposite to the one of the gravitational pull)
- Sub-phase 3 - forward swing to upswing;
- Sub-phase 4 – swing to a handstand with a ½ turn around the vertical axis of the body.

The upswing from a handstand

Sub-phase 1. - upswing from a handstand (Kinogram 2) lasts from the beginning of the movement (handstand) to a balanced support position, in other words, until the moment when the deviation of the shoulder joint point forward is the greatest (*the position when the axis of the shoulders forms a 65° degree angle with the center of the support grasp*). The duration of this phase was 0.52 seconds.

The initial position is the handstand, an unstable balance position. This is the position from which the upswing commences, so that the shoulders move forward, and the body and legs move backward. The characteristic of the upswing is that after the movement commences ***two pendulum systems*** appear - *the hanging pendulum* (the body-feet system) *and the supported pendulum* (the hands and the head).

The hanging pendulum rotates around its axis which passes through the center of the shoulder joints. A decreased retroflexion occurs in these joints, or to be more precise, since it is a case of work with a negative effect (working against gravity), anteflexion occurs (from a value of 147^{o} to a value of 64^{o} at the end of the sub-phase, with an average angular velocity of 209 st/sec - Chart 6, the gray and black triangles).



Kinogram 2. Sub-phase I - upswing from a handstand

The body-feet system, as part of this pendulum, increases in speed on its way down, and decreases in speed on its way back. The peripheral speed (Chart 4 - the white circles in phase I) of the open end of the kinetic chain, *the tips of the feet,* will sharply increase until the end of this phase, until it reaches the value of approximately 5.73 m/s (primarily at the expense of the shift in the "y" direction). Naturally, the value of the peripheral speed of this point is greatest in comparison to all the other referential points in this system, as the point which is the farthest in relation to center of the spin – is the shoulder axis. The axis of the hip joint is also part of this system. During this sub-phase, the hyperextension of the hip joints occurs (Chart 5, the black square in phase I – the values increase from 180^{O} to 200^{O}). The angular velocity of this action is steady almost until the very end of this phase (an average of 86 st/sec), after which a decrease in the movement speed of this joint ensues (Chart 6, the grey spots).

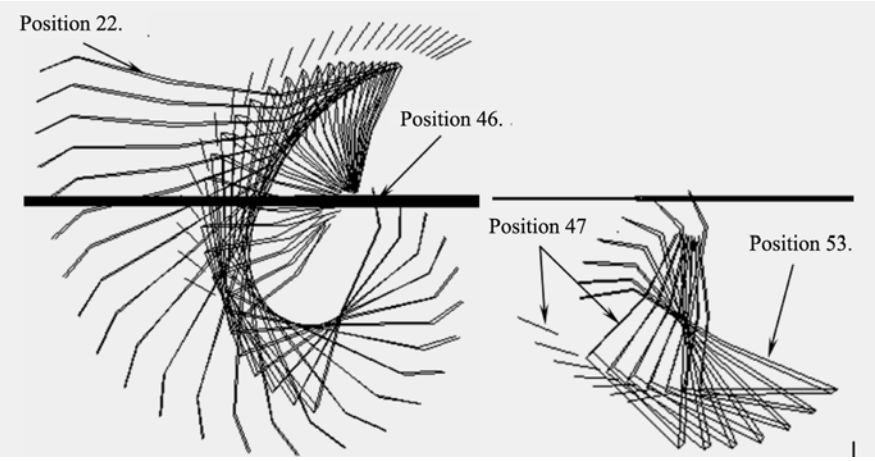
The supported pendulum rotates around the axis which passes through the center of the hand joints. The values of this angle decrease from approximately 90°, at the beginning of the movement, to around 65°, at the end of this sub-phase. The shoulder point moves 0.14 m forward, slowly (Chart 4, the curve of the triangles - the peripheral speed decreases from around 1m/s at the beginning of the movement, to around 0.05 m/s –this point will soon come to a complete stop at the end of sub-phase I). The angle between the vertical axis of the head and the vertical axis of the body decreases (the head bends), from 250° to 199° (Chart 5 - the grey triangles in phase I).

The body's center of gravity quickly moves downwards (Chart 1 - the black squares). The values of the "y" axis decrease significantly, which reflects the almost straight line of this point in its downwards movement, which slightly backward as well. At the end of this phase, the peripheral speed of this point is - 1.70 m/s.

None of the studied points showed any significant shifts along the "z" axis during this sub-phase.

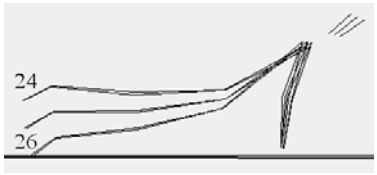
Downswing to upswing

The downswing from a balanced handstand, to the upswing (Kinogram 3) is carried out in the first phase of the forward swing to upswing – before the body of the gymnast reaches the maximum vertical position (the so-called early downswing). The second sub-phase commences from the balanced handstand, by moving the arms-head system backwards, rotating around the axis of the support grip (position 22) and lasts until the beginning of the forward swing to upswing, or to be more precise, until the beginning of the second extension in the hip joint (position 53).



Kinogram 3. Sub-phase II - downswing to upswing

When the TT moves in the same direction as the gravitational pull, gravity has a positive affect on the movement, which is in the same direction as the resulting muscle force vector[1], moving the body downwards and gradually speeding up its movement. The aim of the movement during this phase is to accumulate the greatest amount of kinetic energy as possible and, according to Smolevsky (Smolevsky, 1992; taken from Kolar, 1996) is called THE ACCUMULATION PHASE.

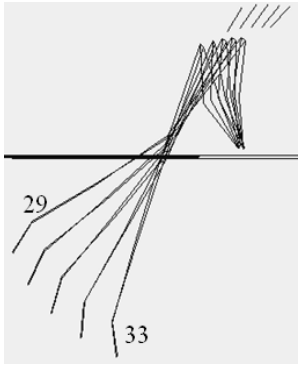


Kinogram 3. Positions 24 - 26

At the beginning of sub-phase II the angular velocity of the retroflexion in the shoulder joint (or to be more precise, the anteflexion, since this is a case of work with a negative effect) starts to decrease (the decrease is for the purpose of better control of the downswing), and the shoulder point, as has already been mentioned, begins its backward journey (the values on the "y" axis - the moving up and down - suffer slight variation) and at a great speed (Chart 4 – the curve of the triangles at the beginning of sub-phase II). The angular velocity of the hip joints (Chart 6 - the grey circles at the beginning of sub-phase II), from the very beginning of sub-phase II begins a short period of increase in the extension velocity of the hip joint (the production of the stretch reflex – up to position 24), after that comes the fall and the onset of flexion in the aforementioned joint.

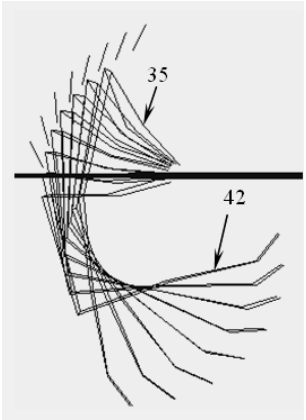
At the moment when the tips of the feet reach the level of the bars (position 26 - the upper arm/"x" axis angle is approximately 70°), flexion begins in the hip joint (Chart 6 - the grey dots).

[1] The resulting muscle force vector represents the sum of the force vectors of all the muscles participating in the given motion or range of motions.



Kinogram 4. The period from position 29 - to 33

What follows *is the second most significant detail of the movement* ***the loss of balance*** – the period between position 29 up to position 33 (the upper arm/"x" axis angle is 100°), when the shoulder point is not aligned with the horizontal axis which passes through the surface of the support. What occurs is the synchronized shift of the shoulders backwards and the movement of the tips of the feet forward, which creates the impression that the hip point does not move and that the body is rotating around this point (a necessary precondition for the correct execution of the upswing and the successful continuation of the movement). In addition, what also starts during this period is the increase in anteflexion in the shoulder joints.

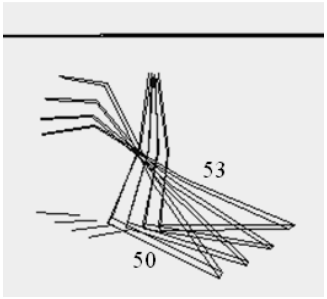


Kinogram 5. The period from position 35 - to position 42

The third most significant detail of sub-phase II – ***achieving maximum angular velocity of anteflexion in the shoulder joint and flexion in the hip joints*** – the period from position 35 to position 42. (the upper arm/"x" axis angle is approximately180°). The greatest values were found in position 41, where the angular velocity of the increase of the angle in the shoulder joints is 249 st/sec and where the angular values have decreased in the angle of the hip joints to 565 st/sec. During this period in the movement the maximum speed of the tips of the feet is achieved (position 35 - 9.67 m/s, after which the tips of the feet enter the anti-gravitational phase which causes a decrease in their speed). The increased head extension also commences (Chart 6 - the black squares).

The decrease in the angular velocity of the increase in the shoulder joints angle (Chart 6 - the black and grey triangles, after position 41, when the shoulder point is below the bars), signals the beginning of the retroflexion, but it is accompanied by work with a negative effect, as there is some opposition to the gravitational pull, which, in addition to the effect of the force of the retroflexion in this joint, still increases the angular value.

In addition to the aforementioned, what is characteristic to this period is the shift in the tip of the feet in the opposite direction from the bars around which the swing takes place (Chart 2 - the black and white dots – phase II), which lasts until the moment of maximal flexion in the hip joints. This could be an indication of the preparatory movements with the aim of creating favorable conditions for the successful realization of the main part of the movement, and that is reaching one bar while simultaneously swinging around the vertical axis. *Namely, this movement allows the muscles which straighten the hips on the left side to stretch, muscles which should play a dominant role in directing the swing of the legs towards the bar around which the swing is taking place during the execution of the turn.*



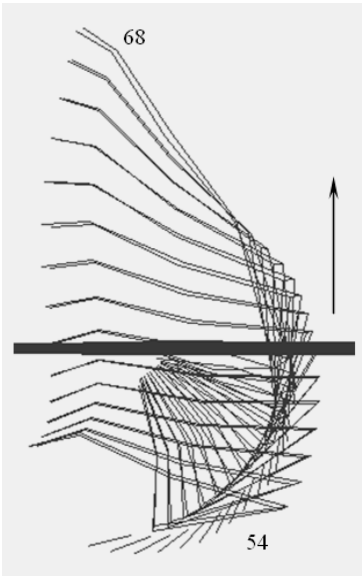
Kinogram 6. The period from position 50 to position 53

The fourth significant detail of sub-phase II is reaching the upswing – the period from position 50 to position 53, when ***retroflexion begins in the shoulder joints, but is accompanied by work with a positive effect*** (with the purpose of lifting the hips, to direct them forward and upward), then, ***the flexion of the head begins and the flexion of the hip joints ends.***. In position 53 the angular value of the hip joints is minimal and is 23°. What is characteristic for this position is that the shoulder point is located directly below the center of the support grasp and that the hip point and the shoulder point are almost on the same level (have almost identical values on the "y" axis).

Changes on the "z" axis are of no significance to the interpretation.

Forward swing to upswing

Sub-phase III (Kinogram 8) begins with the extension in the hip joints from an upswing position (position 54) and lasts until the moment when the right hand releases the bar (position 68). The overall duration of this sub-phase is 0.28 sec. In the position where the force of gravity begins to have a negative effect on movement (the anti-gravity direction), or in other words, when the direction is opposite to the effect of the resulting vector of muscle force, giving the movement negative acceleration, the ACTION PHASE commences (Smolevsky, 1992; taken from Kolar, 1996).



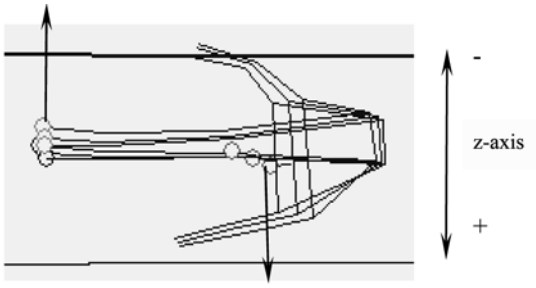
Kinogram 7. Sub-phase III - the forward swing to upswing

At the beginning of this phase (starting from position 53) the shoulder point and the hip point begin their movement in the forward and upward direction (Chart 1 – the curves after point 53), the tips of the feet form a "knot" and are directed mostly upward (changes in the values of the "x" axis are very low - Chart 1 - after point 53). The body's center of gravity starting from position 51 has entered the anti-gravitational phase (the forward and upward direction - Chart 1 - after point 53). The peripheral TT speed (Chart 4 - the red curve in phase III) significantly increases from position 53. The faster movement of this point lasts until position 58 (maximal value - 3.74 m/s), after which, until the end of the movement, it slowly decreases.

The first more significant detail of sub-phase III – ***the beginning of the quickened extension of the hip joints,*** which takes place at the very beginning of the sub-phase, from position 54 (Chart 6 - the grey dots in phase III).

The second more significant detail - ***a more significant movement along the "z" axis –*** the period from position 59 (the shoulder/"x"axis angle is 55°).

The movement of all the referential points (except the shoulder point) begins once the gymnast has passed through the upswing (from position 54) towards the bar around which the swing takes place (to the left). A significant detail in the sub-phase is position 59, which is the starting point of the enhanced leg shift towards the bar around which the swing is executed and the start of the shift of the top of the head in the opposite direction (away from the bar around which the swing is being executed - towards the right bar - see Chart 2 – the white and black squares in phase III). The legs are extended, and the head continues its stretch. What is characteristic for this period is the sudden increase in angular velocity of the retroflexion of the right shoulder.

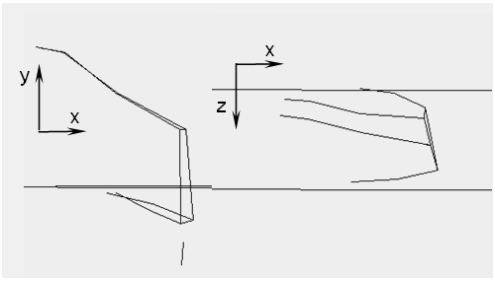


Kinogram 8. The period from the 59th till the 61st position – the direction of the movement of the tip of the feet and the top of the head along the "z" axis

The third more significant detail – ***the beginning of an increased anteflexion in the left shoulder and the continuation of the increased retroflexion in the right shoulder*** – the period from the 61st position. It is from this position that the sudden increase in the left shoulder angle and the decrease in the angle of the right shoulder occurs (Chart 5 - the black and white dots in phase III), which signals that the left arm is used to execute the anteflexion movement and apply pressure on the bars towards release, and the right arm is used for the retroflexion movement and the pressure on the bar towards a grasp.

Movements that are synchronized in such a manner enable the rotation of the shoulder axis and the shift of the body towards the bar on which the turn is being executed.

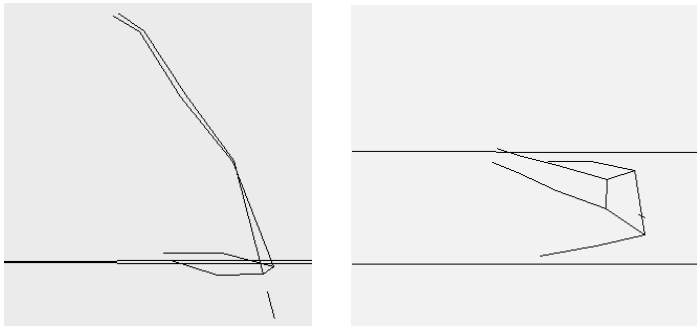
The fourth more significant detail – ***achieving the maximum speed of the tips of the feet and a post-active transfer of the swing*** - the period from position 65.



Kinogram 9. Position 65

The tips of the feet achieve their maximum peripheral velocity at the 65th position, with a value of 7.94 m/s. The maximum extension velocity of the hip joints is achieved in position 67 with a value of 690 st/sec, and with an achieved angle of 136°. The angle formed by the forearm and the "x" axis in this position is approximately 20° below the bar. These positions are followed by a sudden decrease in the speed of the tip of feet, which signals the onset of the post-active transmission of the swing from the feet to the body. The aforementioned, primarily, enables the onset of the movement of the right shoulder point towards the bar on which the turn is being executed (see Chart 3 – phase III). In addition, an increase in the value of the peripheral velocity of the shoulder point occurs (Chart 4 - the black and white trian-

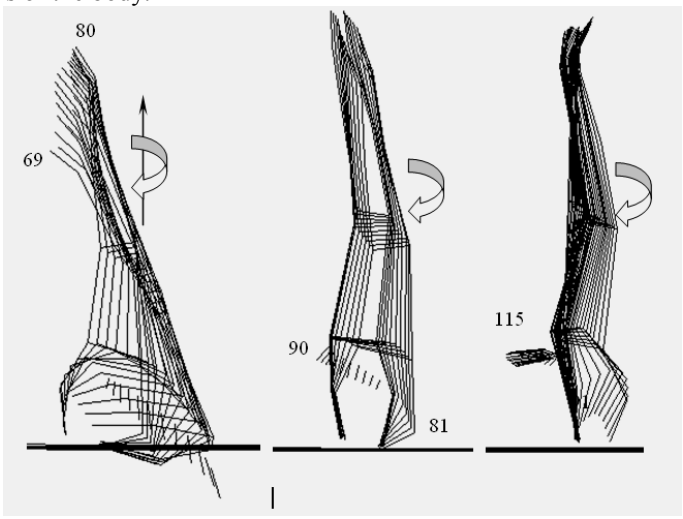
gles - starting from position 67.), whose trajectory on the "xy" plain is still aimed forward and upwards. In addition, the post-active swing transfer signalizes the moment when to release the bar with the right hand, which takes place in position 68. During the forward swing to upswing, in addition to the extension in the hip joints, the torsion and lateral flexion of the spinal column also occurs, with the intent to create favorable conditions for rotation around a vertical axis and to transfer the body's center of gravity to a position above the support bar.



Kinogram 10. Position 68 - the moment the right hand releases the bar

A swing with a ½ turn around a vertical axis to a handstand

The fourth sub-phase (Kinogram 12) begins once the right hand has released the bar (position 68), and ends with a handstand (position 115). The duration of this sub-phase is 0.94 seconds. All of the energy that is accumulated during the first three sub-phases is used for the execution of the upswing to a handstand with a simultaneous rotation around the vertical axis of the body.



Kinogram 11. Sub-phase IV – a swing with a 1/2 turn to a handstand

During the execution of sub-phase IV, it is necessary, to point out the following important details in order:

A sudden change in the direction in which the shoulder point is moving takes place after the right hand releases the bar (starting from position 68). A quicker horizontal adduction and anteflexion of the shoulder of the freed hand begins. Flexion begins in the elbow joint of both the freed and the supporting hand. Until position 70, the tips of the feet, as has already been mentioned, move towards the support bar, after which they start moving towards the middle of the horizontal bar. After position 76, a sudden drop in the value of the peripheral velocity occurs in the shoulder points and as well as a decrease in the angular velocity in the shoulder joints. In position 77 we note the maximum bending of the elbow of the support arm, which is approximately 90°. The extension of the elbow joints begins from the position when the right hand grabs hold of the left bar (position 80).

From position 81 to position 90, a further push towards the handstand with both arms ensues (extension in the elbow joints and the continuation of the anteflexion in the shoulder joints). A 90° turn is first completed by the shoulders (in position 80 when the values on the "z" axis for the shoulder points match - see Chart 3 the black and white triangles in phase IV), and then the hips (in position 89) and finally the tips of the feet (in position 91).

The second part of the turn begins with position 91 (the left hand releases the left bar), and the gymnast reaches the handstand on both bars. All of the activities in this part of the movement are begun with the aim of position improvement and the successful execution of the movement.

4. CONCLUSION

The kinematic model of the Basket with ½ turn to handstand on the parallel bars, determined on the basis of the results of the kinematic and expert analysis, presupposes the existence of two phases (the gravitational and anti-gravitational) and four sub-phases:

Sub-phase I - *Upswing from a handstand to a balanced forward handstand* lasts from the beginning of the movement (the handstand) until the maximum bending of the shoulder point forward. Up to this position, the first system (the body, the legs) quickly falls downwards rotating around the axis drawn through the centre of the shoulder joints, while the other system (the arms and the head), rotating around the center of the support, is moved forward in a compensatory and slower manner.

Sub-phase II - *Downswing to upswing* begins with the balanced handstand, by moving the arms-head system backwards, rotating around the axis of the support grip, where the retroflexion in the shoulder joints and the extension in the hip joints is slowed down. When the shoulder point exits the surface of the support, increased flexion in the hip joints and anteflexion in the shoulder joints begins, whose maximum values occur in the positions where the shoulder point reaches the level of the bars. Once the shoulder point reaches the lower vertical axis, the retroflexion in the shoulder joints begins, accompanied by work with a positive effect (with the intention of lifting the hips, directing them forward and upward). In this part, the movement begins with the flexion of the head and ends with the flexion of the hip joints.

Sub-phase III - *Forward swing to upswing* begins when the shoulder point passes through the bottom vertical axis and with the increased stretching of the hip joints from

the upswing. When the arms form an angle of approximately -55° with the "x" axis, more significant movements on the "z" axis occur, or to be more precise, an emphasized movement of the legs towards the bar around which the turn is being executed, and the top of the head in the opposite direction. After that, when the arms form a -45° degree angle with the "x" axis (the middle of the sub-phase) a turn to the left a turn around the vertical axis of the body begins, aided by the increased anteflexion in the left shoulder and the continuation of the increased retroflexion in the right shoulder. The post-active transfer of the swing from the legs to the body begins with the arrival of the shoulder point to the level of the bars, which enables the gymnast to release the bar with his right hand and to enter the final sub-phase.

Sub-phase IV – *A swing to a handstand with a ½ turn around the vertical axis of the body* begins with the exit of the shoulder point to a point above the bars and the release of the bars on the part of the right hand. The sub-phase continues with a 90^{O} turn around the vertical axis of the body, around the left arm, to the left, until the gymnast reaches the head-on handstand and it ends with a 90° turn and a shift to the handstand to the side (thus ends the second phase).

A kinematic model defined in such a way, due to its high informative value, will certainly facilitate the process of technical preparation for the analyzed exercise and the process of creating a methodological training procedure which should first be aimed at the acquisition of each individual phase (the analytical method), and then, the successive merging of all the sub-phases, with a multiple execution of the entire exercise (the synthetic method), by merging with the previous and following exercises in a gymnastics program and finally with the successful execution of the entire program on the parallel bars.

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KINEMATIČKI MODEL KOVRTLJAJA NAZAD IZ STAVA U UPORU DO STAVA U UPORU SA 1/2 OKRETA NA RAZBOJU BOČNO

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Istraživanje je imalo za cilj da izvrši kinematičku analizu kovrtljaja nazad iz stava u uporu do stava u uporu sa 1/2 okreta na razboju bočno, kako bi se stvorili preduslovi za uspešno koncipiranje procesa obučavanja i usavršavanja pomenutog elementa. Realizator uspešnog kovrtljaja do stava u uporu bio je Mitja Petkovšek, slovenački reprezentativac i jedan od najuspešnijih vežbača na paralelnom razboju u protekla dva olimpijska ciklusa u Svetu. Kinematički parametari su utvrđeni upotrebom 3-D video sistema za kinematičku analizu APAS i korišćenjem Sušankinog telesnog modela (Čuk, 1996), koji uvažava 17 referentnih tačaka i 15 segmenata. Rezultati istraživanja omogućili su definisanje kinematičkog modela vežbe, koji predviđa postojanje gravitacione i antigravitacione faze i četri podfaze (odnjih iz stava u uporu, spad do visa uznetog, prednjih u visu uznetom i uzmak sa 1/2 okreta oko uzdužne ose tela). Preporuka za još uspešnije izvođenje analizirane vežbe je kasnija realizacija postaktivnog prenosa zamaha sa nogu na telo u III podfazi i kasnije napuštanje pritke jednom rukom na početku IV podfaze.

Ključne reči: *kinematička analiza, ekspertna analiza, paralelni razboj, Kovrtljaj nazad iz stava u uporu do stava u uporu sa 1/2 okreta, gravitaciona faza, antigravitaciona faza*