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Original empirical article

THE KINEMATIC MODEL OF THE BASKET TO HANDSTAND ON THE PARALLEL BARS

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Abstract. *A model of a successful routine for competitors in artistic gymnastics consists of the most complex coordination elements and their successful execution. One of the most difficult elements on the parallel bars is a "basket to handstand" The aim of the research was to carry out a kinematic analysis of the element basket to handstand on the parallel bars, in order to ascertain the conditions for the successful construction of the teaching process, which would help in perfecting the element. Mitja Petkovšek, a member of the Slovenian national team and one of the most successful competitors on the parallel bars in the last two Olympic cycles, successfully performed a basket to handstand. Kinematic parameters were determined by using a APAS 3-D video system for the kinematic analysis and which included 17 reference points and 15 body segments. The results of the research defined the kinematic exercise model, which requires four phases 1) upswing from a handstand 2) downswing to upswing; 3) forward swing to upswing; 4) downswing to handstand. A kinematic model, defined in this way, will as a result of its highly informative value undoubtedly facilitate the process of technical preparation for the analysed element. It will also facilitate the process of creating a methodological training procedure, which should first be aimed at the acquisition of each individual phase (the analytical method), and afterwards should concentrate on the successive merging of all the phases, with a multiple execution of the entire element (the synthetic method).*

Key words: *kinematic analysis, swing, gymnastics.*

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INTRODUCTION

A model of a successful routine for competitors in artistic gymnastics consists of the most complex coordination elements and their successful execution. One of the most difficult elements on the parallel bars is a "*basket to handstand*" (basket – see Fig. 1). The element is quite popular among gymnasts, as it can be upgraded into more difficult and complex elements (by adding another ½ and 1/1 turn) and can also be performed in combination with other complex elements of the D, E and F level of difficulty from the same group or from other structure groups (Stoika et al., 2009).

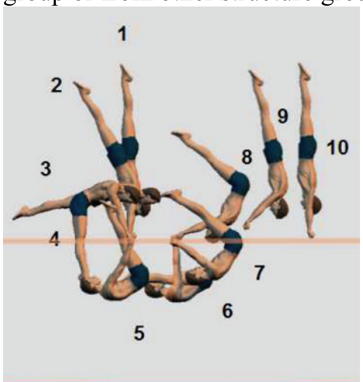


Fig. 1. Basket to handstand.

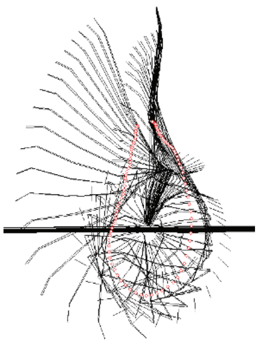
A rational and economical process of teaching and perfecting the basket requires a detailed analysis, particularly in terms of learning details, which are not readily available to the visual inspection of the coach and the kinaesthetic receptors of the gymnast performing the element. Research on the kinematic analysis of a certain kind of movement is becoming more and more frequent in artistic gymnastics, particularly as the information obtained enables more rational and economical instruction and acquisition of the analysed movement (Heng, 2007; Hiley & Yeadon, 2007; Takei, 1998; Brüeggmann et al., 1994). Very few research papers have dealt with the kinematic analysis of the parallel bars elements. Linge et al. (2006) dealt with the modelling of the parallel bars in Men's Artistic Gymnastics. Prassas & Ariel (2005); Prassas (1994) dealt with the kinematics of giant swings and back toss on the parallel bars, as well as Tsuchiya et al. (2004) who dealt with the kinetic analysis of the same element. The double back salto dismount from the parallel bars was the research topic of Gervais & Dunn (2003). Additionally, there were many research papers which deal with the comparative study of two similar elements. Kolar E., Kolar KA., Kolar (2001) conducted comparative analyses of selected biomechanics 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 research of new elements. 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". Previous research focused on the Basket (felge) to handstand mount on the parallel bars (Takei & Dunn, 1996). The mount starts from a standing position from which the gymnast jumps into the swing. The performances of 26 national gymnasts were split into two groups by score and then analysed. It was found that better performances were associated with a higher mass centre position and vertical velocity during release. It was also observed that in the poorer performances the gymnasts over-rotated before releasing the bars, which led to a poor body position on re-grasp. Being over-rotated during the release would result in the gymnast re-grasping the bars at a larger angle between the body and the vertical axis. To achieve the handstand from this position the gymnast would be required to press to the handstand, incurring deductions from the judges. Recent research has dealt with the optimization of the techniques of the exercise performance, where some are specifically related to the optimization of the basket to handstand technique (Hiley & Wangler, 2009). Two male gymnasts each performed nine trials of the felge from handstand to handstand while data were recorded using an automatic motion capture system. The highest and lowest scoring trials of each gymnast, as determined by four international judges, were chosen for further analysis. The technique used by each gymnast was optimized using a computer simulation model so that the final handstand position could be achieved with straight arms. For the purpose of optimization, different techniques were identified in the coaching literature that are used by gymnasts. Optimum simulations resulted in improved performances through a combination of increased vertical velocity and height of the mass centre at release. Although the optimum technique found close to the gymnasts' own technique was more demanding in terms of the strength required, it offered the potential for a more consistent performance and future developments in skill complexity. The aim of the present article is to carry out a kinematic analysis and to determine the kinematic model of the "*basket to handstand*" element, which creates the necessary preconditions for the successful execution of the technical preparation of this exercise. The data can be used as a basis for further optimizing the application performance of other athletes who want to train this particular element (Hanin & Hanina, 2009).

THE METHOD

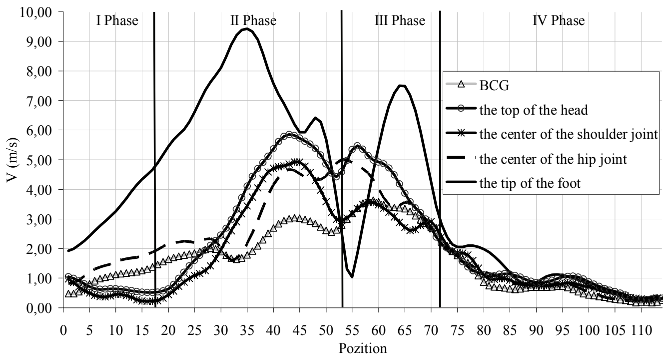
Kinematic analysis was carried out on a single successful attempt of the basket element (without any visible technical and aesthetic errors). The element was performed during training by one of the most successful competitors on the parallel bars in the world, a member of the Slovenian national sports 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 present the stick figures, an Ariel Performance 3D video system was used for the kinematic analysis (APAS). All of 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 analysed, and the centre of the coordinate system was at the beginning of the parallel bars (2m from the centre of the support grip). As part of the kinematic analysis, a digitalisation of the 15-segment competitor model was carried out (2). As the performed element has the characteristics of a two-dimensional movement, 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 analysed (the body centre of gravity, the tip of the right foot, the centre of the right shoulder joint, the centre of the right hip joint and the top of the head), ***the speed of the referential points*** (the body centre of gravity, the tip of the right foot, the centre of the right shoulder joint, the centre of the right hip joint and top of the head), ***the goniometric characteristics:*** *the angle* (the right hip joint, the right shoulder joint) and *the angular velocity* (the right hip joint, the right shoulder joint). The research was conducted in accordance with the ethical standards of the Helsinki Declaration.

THE RESULTS

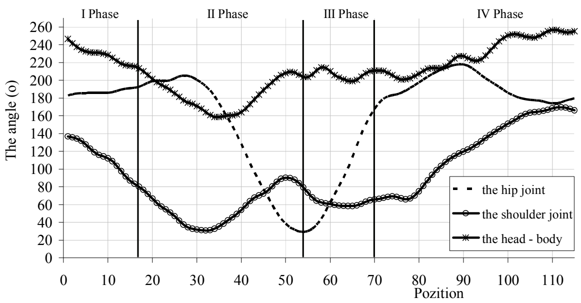
The kinematic analysis comprises the analysis of the stick figure and the graph, representing the values for peripheral speed, the goniometric characteristics and the angular velocity of the referential points and segments of a successful repetition. It is possible to establish 115 positions in a single stick figure for a movement lasting 2.3 seconds (one for every 0.02 seconds - Stick figure 1). Graph 1 shows the values of the peripheral speed, Graph 2 presents the goniometric characteristics and Graph 3 shows the ante flexion in the shoulder joints and the extension of the hip joints, while the negative values represent the retro flexion in the shoulder joints and flexion in the hip joints.



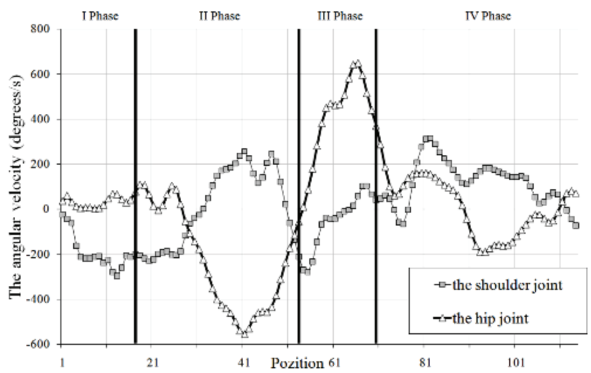
Stick figure 1. Basket to handstand (Mitja Petkovšek).



Graph 1. The peripheral speed of the referential points during the execution of the basket.



Graph 2. The angle of the referential segments during the execution of the basket.



Graph 3. The angular velocity between the referential segments during the execution of the basket.

In the execution of the basket element, two mobile axes of rotation can be noticed apart from a fixed axis around which the entire system of points revolves (Fig. 2):

a) an axis, passing through the centre of the shoulder joint, around which the body-legs system rotates;

b) an axis, passing through the centre of the hip joint, around which the legs rotate as the free end of the kinetic chain.

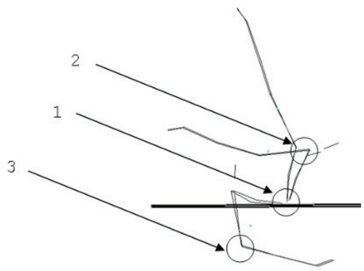


Fig. 2. Axes of rotation – 1 the fixed axis – the support; 2 the shoulder joint axis; 3 the hip joint axis.

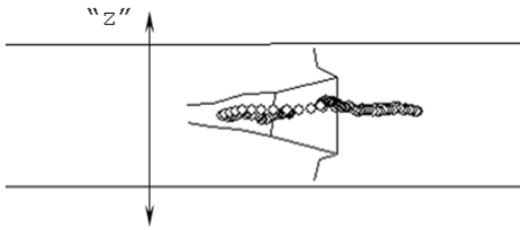


Fig. 3. The trajectory of the body centre of gravity on the horizontal plane.

The movement is two-dimensional, and is performed in the sagittal plane (on the "xy" plane); any greater deviations along the "z" axis can be characterised as an error in the execution, or to be more precise, a deviation from the ideal execution technique (see Fig. 3). Established kinematic parameters have enabled the division of the entire movement into four clearly identifiable phases:

1. ***Upswing from a handstand to a balanced position of forward support***: lasts from the beginning of the movement, until the point of the greatest deviation of the shoulder point forwards (up to position 17 – a total of 0.34 s.);

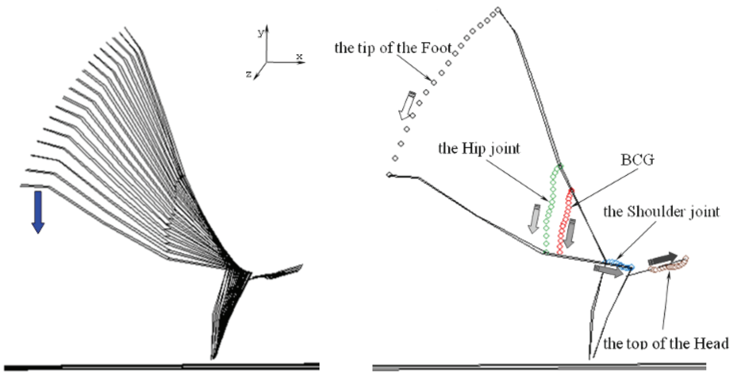
2. ***Backward downswing from a handstand to upswing***: lasts from the beginning of the movement of the shoulder point backwards (position 18), until the maximal flexion of the hip joints (position 53 – a total of 0.72 s.);

3. ***Forward swing to upswing***: lasts from the beginning of the extension of the hip joints (position 54), until the moment when there is no more contact with the bars (position 70 – a total of 0.34 s);

4. ***Swing to handstand*** – lasts from the beginning of the no-support phase (position 71) until the end of the movement (position 115 – a total of 0.9 s).

THE DISCUSSION

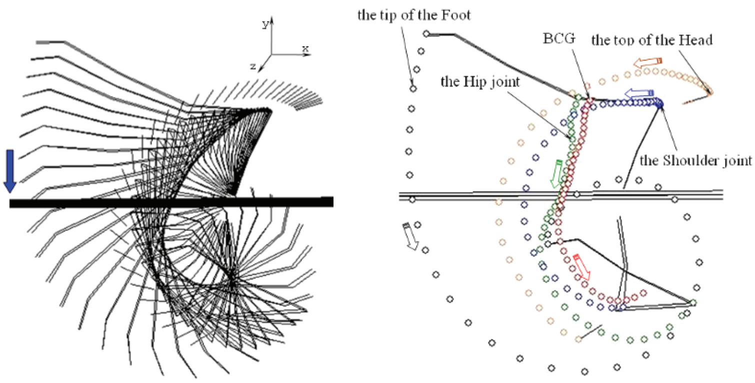
Phase 1: UPSWING FROM THE AHANDSTAND



Stick figure 2. The trajectory of the points on the "xy" plane - phase I.

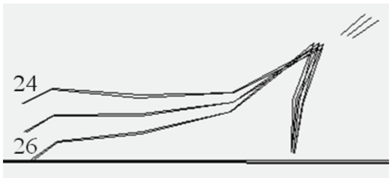
Phase I: UPSWING FROM THE HANDSTAND (Stick figure 2) lasts from the beginning of the movement (handstand) to a balanced handstand, in other words, until the moment when the deviation of the shoulder joint point forward is the greatest (*the position when the axis of the shoulders forms a 65^{O} degree angle with the centre of the support grasp*). 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 centre of the shoulder joints. A decreased retro flexion occurs in these joints, or to be more precise, since it is a case of work with a negative effect (working against gravity), ante flexion 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 ^{O}/s - the grey squares). 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 (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 the centre of the spin – 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 (the dotted line 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 ^{O}/s), after which a decrease in the movement speed of this joint ensues (the white triangles). ***The supported pendulum*** rotates around the axis, which passes through the centre of the hand joints. The values of this angle decrease from approximately 90^O, at the beginning of the movement, to around 65^O, at the end of this sub-phase. The shoulder point moves 0.14m forward, slowly (the curve with the cross-like marks - 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 phase I). The angle between the vertical axis of the head and the vertical axis of the body decreases (the head bends), from 250^O to 199^O (the curve with the cross-like marks in phase I). ***The body centre of gravity*** quickly moves downwards (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 is slightly backwards as well. At the end of this phase, the peripheral speed of this point is - 1.70 m/s.

PHASE II: DOWNSWING TO UPSWING



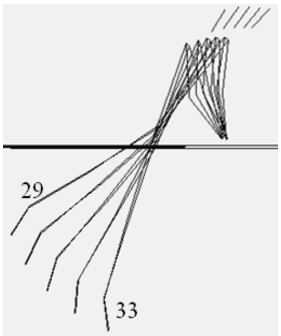
Stick figure 3. The trajectory of the points on the "xy" plane – phase II.

The downswing from a balanced handstand, to the upswing (Stick figure 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 – 0.44s) 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 – 1.06 s). When the BCG (body centre of gravity) moves in the same direction as the gravitational pull, gravity has a positive effect on the movement, which is in the same direction as the resulting muscle force vector (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), 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 is called THE ACCUMULATION PHASE.



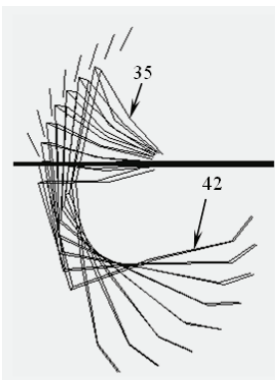
Stick figure 4. Positions 24 (0.48s) – 26 (0.52s).

At the beginning of phase II the angular velocity of the retro flexion in the shoulder joint (or to be more precise, the ante flexion, 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 movement up and down - suffer slight variation) and at a great speed (the curve with the cross-like marks at the beginning of phase II). The angular velocity of the hip joints (Graph 3 – the curve with triangles at the beginning of phase II), from the very beginning of 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 – 0.48s), 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 – 0.52s - the upper arm/"x" axis angle is approximately 70^{O}), flexion begins in the hip joint (the dotted curve).



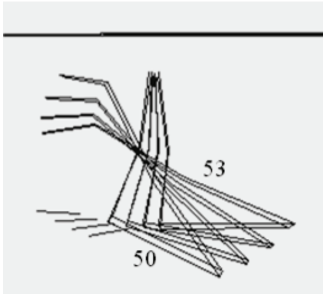
Stick figure 5. The period from position 29 (0.58s) to 33 (0.66s).

This is the second most significant detail of the movement: ***the loss of balance*** – the period between position 29 (0.58s) up to position 33 – 0.66s (the upper arm/"x" axis angle is 100^{O}), 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 hips do 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 ante-flexion in the shoulder joints.



Stick figure 6. The period from position 35 (0.70s) to position 42 (0.84s).

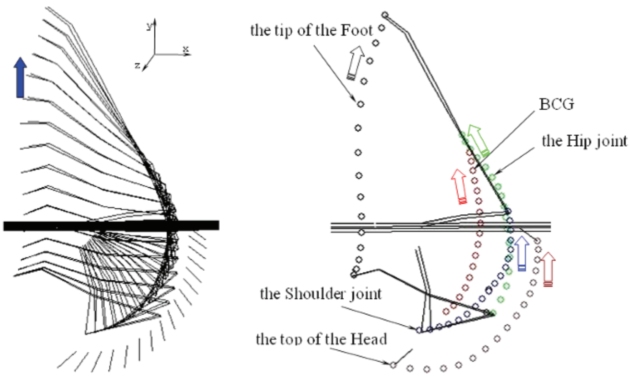
The third most significant detail of phase II – achieving maximum angular velocity of ante flexion in the shoulder joint and flexion in the hip joints – the period from position 35 (0.70s) to position 42. – 0.84s (upper arm/"x" axis angle is approximately180^{O}). The greatest values were found in position 41 (0.82s), where the angular velocity of the increase of the angle in the shoulder joints is 249 ^{O}/s and where the angular values have decreased in the angle of the hip joints to 565 ^{O}/s. 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 (the black curve with squares). The decrease in the angular velocity and the increase in the shoulder joints angle (the grey squares, after position 41 – 0.82s, when the shoulder point is below the bars), signals the beginning of the retro flexion, 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 retro flexion in this joint, still increases the angular value.



Stick figure 7. The period from position 50 (1.00s) to position 53(1.06s).

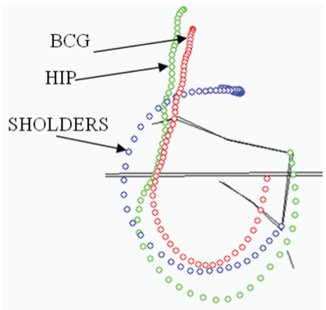
The fourth significant detail of phase II is reaching the upswing – the period from position 50 (1.00s) to position 53 (1.06s), when retro flexion begins in the shoulder joints, but is accompanied by work with a positive effect (with the purpose of lifting the hips, to direct them forward and upward); then, the flexion of the head begins and the flexion of the hip joints ends. In position 53 (1.06s) the angular value of the hip joints is minimal and is 23^{O}. A characteristic of this position is that the shoulder point is located directly below the centre 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).

Phase III: FORWARD SWING TO UPSWING

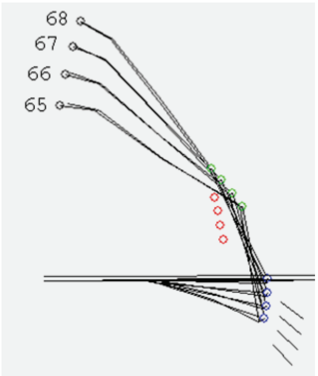


Stick figure 8. The trajectory of the points on the "xy" plain – phase III.

Phase III begins with the extension of the hip joints from an upswing position and lasts until the moment the hands release the bar (the no-support phase). The first significant detail of this phase is the very beginning - *positions* 54 (1.08s) and 55 (1.10s) – marked by the onset of the quickened extension of the hip joint and the quickened movement of the tips of the feet upward. This action enables an increase in the peripheral speed of the lift of the body's centre of gravity (the white triangles in phase III).



Stick figure 9. Position 62. (1.24s).

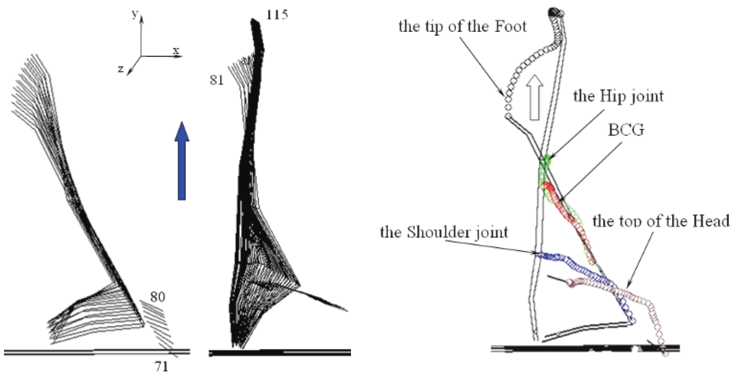


Stick figure 10. The period during which the maximal angular velocity of the extension of the hip joint is achieved.

The second significant detail of the movement starts with position 62 (1.24s - Stick figure 9), when the increased ante flexion in the shoulder joints begins. At the moment when the body centre of gravity reaches the level of the bars and the hip point begins its journey upward and backward, the movement of the quickened ante flexion begins in the shoulder joints. This action enables the increase of the peripheral speed of the climb of the hip point and the relative stabilisation of the peripheral speed of the rise of the body centre of gravity. In the aforementioned position, the angle of the shoulder joints is somewhat less than 60^{O}, and of the hip joints is somewhat greater than 80^{O}.

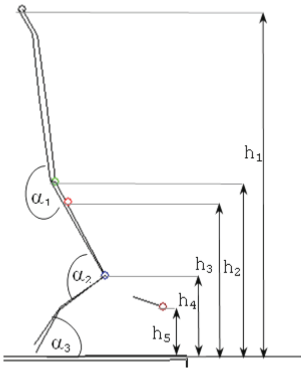
The third important detail of the movement begins with position 65 (1.30s) – the maximum speed of the tips of the feet and the angular velocity of the extension of the hip joint (Stick figure 10). In the moment when the angular velocity of the ante-flexion reaches its maximum during this phase of the movement, the extension of the hip joint reaches its maximum. The peripheral speed of the climb of the tips of the feet in position 65 (1.30s) is 7.8 m/s, and the angular velocity of the speed of the extension in the hip joints in position 67 (1.34s) is 670 ^{O}/s. Starting from position 68 (1.36s), when the shoulder point reaches the level of the bars, this marks the onset of the sudden decrease of the aforementioned values. The behaviour of these kinematic parameters signals the existence of a post-active transfer of the swing from the legs to the entire body. The sudden rise of these values from the beginning of phase III indicates the ballistic character of the contraction of the hip extensor. The sudden decrease in speed from position 67 (1.34s) indicates that the muscle extensors are no longer active in the hip joints and the flank section of the spinal column, and that their antagonists begin to function. The energy to carry the legs in the direction, in which the swing is being executed, is post-actively transferred to the upper body. This can be seen in Graph 1 – phase III, in the case of the peripheral speed of the shoulder point (the curve with the cross-like marks – an increase in value from position 66 – 1.32s to position 70 – 1.40s). The lower extremities and the pelvis behave as the sealed-off end of the kinetic chain, so that the muscles that bend the hip joints and the spinal column function with a peripheral support. During the post-active swing transfer what occurs is the unloading of the pressure onto the support by means of the bar, so that the ante-flexed muscles of the shoulder joints can, dynamically speaking, act and take part in the shift of the unburdened upper body in the direction of the executed swing (phase III – the curve with the grey squares – an increase in the angular speed of the ante flexion of the shoulder joints). It is necessary to mention that on the basis of the trajectory of the referential points, it is possible to detect and add muscular force to kinetic energy (which actually takes place during a swing). The gymnast is able to reach the onset point by adding energy in the third quadrant of the swing, that is, during the phase when the movement is being carried out in the anti-gravitational direction. The additional energy is made visible through the realized muscle force, moving in the direction from the body centre of gravity to the centre of the rotation. ***Thus, the radius of the rotation is decreased.*** Namely, all the reference points in the third quadrant are closer to the fixed axis of rotation than they are in the first and second quadrant. The maximum deviation of the body centre of gravity from the centre of the rotation along the x axis is 0.13 m greater during the gravitational phase. The situation is not much different for the other referential points: the maximum deviation of the hip point from the centre of the rotation (the support) along the x axis is 0.04 m greater during the gravitational phase, the shoulder point 0.12 m, the tips of the feet 0.94 m, the top of the head 0.76 m. In this case, the effect of the muscle force is divided into its components, one of which is radial and functions along the radius of the newly formed arch, toward the centre of that arch, and decreases the radius of the rotation, and the second component in a tangent-like manner affects this precise radial component, as the tangent to the arch of the new movement. It represents an addition to the kinetic energy, which should be enough to at least partially compensate for the loss of kinetic energy caused by friction and resistance. It is then that the moment of inertia undergoes a change as well, so that the speed of the rotation increases (Graph 1 – phase III – the curve with the triangles and the cross-like marks – the quickened movement of the body centre of gravity and the shoulder point up to position 59 – 1.18s). The action phase is to a great extent facilitated by the elastic features of the bars. During the movement in the direction of gravity, the central part of the bars (the place of support) moves downward, and during the movement in the anti-gravitational direction, they return to their original position.

Phase IV: SWING TO HANDSTAND



Stick figure 11. The trajectory of the points on the "xy" plane – phase IV.

During the accumulation phase, the gymnast attempts to increase the moment of the amount of the movement by distancing the BCG from the centre of the rotation. During the action and execution phases, the gymnast moves in the direction opposite to the gravitational force. Energy accumulated in the first, second and third phase is then used in the movement during the non-support phase, or to be more precise, for the transition from the forward swing and upswing to a handstand and the further thrust to the handstand. Phase IV begins when the gymnast leaves the bars and moves on to the short non-support phase, after which he re-grasps the bars and thrusts towards a handstand. During the flight phase the body centre of gravity moves along a trajectory defined by the resultant of all the forces, which affected the body in the moment when the gymnast released the bars, the angle at which the effect of this resultant is directed in and the gravitational phase. The non-support part occurs between positions 71 (1.42s) to 80 (1.60s) and lasts 0.18 seconds. *The hyperextension action in the hip joint is synchronised with the ante flexion in the shoulder joint (the hips push forward, the feet backward, with a simultaneous thrust to the bars), so that the body centre of gravity could be brought above the surface of the support in the most correct manner.* After the non-support phase, ***the next significant detail in the movement is -*** position 81 (1.62s) – ***re-grasping the bars.***



Stick figure 12. Position 81 (1.62s).

The moment when the gymnast grasps the bars, the tips of his feet are at a height of 1.7 m (h_1) and are 0.08 m behind the support, the hip point is at a height of 0.9 m (h_2) and is 0.06 m in front of the support, the body centre of gravity is at a height of 0.77 m and is 0.2 m in front of the support and the shoulder point is at a height of 0.4 m (h_4) and is 0.4 m in front of the support. The angle of the hip joint is 198^{O} (α_1), in the shoulder joint is 93^{O} (α_2) and between the upper arms and the x axis is 52^{O}. After the re-grasp the gymnast continues the ante flexion in the shoulder joints and the hyperextension in the hip joints, with the intention of brining all of the points above the line of the supporting order to create an unstable balance position – the handstand. The trajectory of the point of the top of the head, the shoulder joint, the hip joint and the body centre of gravity are sharply moved backward, towards the vertical line, which passes through the support, and the tips of the feet move forward, in front of the abovementioned vertical line. Starting from position 90 (1.80s) the flexion of the hip joint begins, with the aim of correcting the final position. The final position is the handstand.

CONCLUSION

Most coaches and top-level athletes recognize the importance and the need to maintain and further improve technical skills. What needs to be done is intuitively clear, but how to identify individually optimal techniques, how to control them under conditions of competitive stress, and how to do rapid, necessary, and often radical corrections is usually not quite clear (Hanin & Hanina, 2009). Thus, there is a need for a practical and research-based tool to cope with difficulties in the performance of top-level athletes as a special group of expert performers with extensive experience in intensive training and competition. A kinematic model, defined in this way, will as a result of its highly informative value undoubtedly facilitate the process of technical preparation for the analysed element. It will also facilitate the process of creating a methodological training procedure, which should first be aimed at the acquisition of each individual phase (the analytical method), and afterwards should concentrate on the successive merging of all phases, with a multiple execution of the entire element (the synthetic method). Later, the previous and following elements should be added into a routine and finally the successful execution of the entire routine on the parallel bars can be achieved. The obtained information can serve as a basis for further applications which could optimize the performance of other athletes at the national and international level.

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KINEMATIČKI MODEL KOVRTLJAJA NAZAD IZ STAVA U UPORU DO STAVA U UPORU NA PARALELNOM RAZBOJU

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Model uspešne rutinske vežbe za takmičare u artističkoj gimnastici sastoji se od najsloženijih koordinativnih vežbi i njihovog uspešnog izvođenja. Jedan od najtežih elemenata na razboju je "kovrtljaj unazad iz stava u uporu do stava u uporu". Cilj ovog rada bio je da se izvrši kinematička analiza i da se odredi kinematički model elementa "kovrtljaj unazad iz stava u uporu do stava u uporu". Element je *uspešno izveo jedan od najboljih svetskih takmičara na razboju u poslednja dva Olimpijska ciklusa - Mitja Petkovšek. Za kinematičku analizu je korišćen Ariel Performance 3D video system i podrazumevaoo je referentni sistem od 17 tačaka i 15 segmenata ljudskog tela. Rezultati: Rezultati istraživanja definisali su kinematički model koji se sastojao iz četiri faze: 1) zamah naviše od stave u uporu do pozicije ravnoteže prednjeg oslonca; 2) zamah naniže unazad od stava u uporu do zamaha naviše; 3) zamah unapred do zamaha naviše; 4) zamah do stava u uporu. Kinematički model, definisan na ovaj način, nedvosmisleno će ubrzati proces tehničke pripreme analiziranog elementa. On će takođe, ubrzati proces metodološkog pristupa treningu, čiji će prvi cilj biti ostvarenje svake pojedinačne faze (analitički metod), a posle toga će biti skoncentrisan na sukcesivno mešanje svih faza, sa višestrukim izvođenjem celog elementa (sintetički metod).*

Ključne reči: *kinematička analiza, zamah, gimnastika.*