# MODEL CHARACTERISTICS OF HIGH JUMPERS' COMPETITIVE ACTIVITIES

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***Summary***
*Many scientists studied anthropometric characteristics and kinematic parameters of high jumpers. A number of researches were conducted with the aim to supplement and broaden the existing information. First class track and field achievements are not possible without analysis of adequate biomechanical parameters, which is nowadays the area of scientific study in the field of sport. We made a conclusion based on numerous researches that it is not possible to reach top results without the adequate analysis of the training process. Kinematic parameters of last steps of run-up, take-off and flight, which are velocity, knee angles, angles of hip joint, centre of mass (COM) height and others were obtained through the analysis of various researches data. Based on all the parameters mentioned, this text singles out model characteristics of the competitive activities of best ten high jumpers in the recent years.*

***Key words:*** *high jump, biomechanics, angle, velocity, analysis.*

## INTRODUCTION

During the recent years fosbery-flop technique has taken the leading position at the competitions through out the world. Richard Fosbury used the backward twisting high jump technique for the first time at the Olympic Games in Mexico City in 1968. The technique comprised, and still comprises two main characteristics: curved approach (run-up) and backward crossing of the bar. This technique proved the most efficient so far. High jump can be divided in four phases: run-up, take-off, flight and landing. Run-up is comprised of the first part that is straight run-up, which turns into curve running of four to six steps before the take-off. During this phase, the jumper's speed reaches 8 to 9 m/s. Based on the past researches (Iiboshi et al. 1991; Bruggemann and Arampatzis 1997), we can also compare cinematic parameters of more recent ones, where increase of horizontal speed of approach running (Isolehto 2003) is clearly visible. The purpose of such a run-up is to bring the jumper into the optimal position for take-off, which is in consistency with his speed-strength abilities (Hay 1993). Take-off phase is defined as a period between the moment the take-off foot touches the ground at the bounce spot and the moment the foot leaves it. Many scientists studied the anthropometric characteristics of high jumpers, thus concluding they should be tall, fast, with low body mass and capable to develop appropriate speed during the last run-up steps. Numerous researches were conducted with the aim to supplement and broaden the existing information in the professional literature. However, nowadays we can witness that various constitutional types of jumpers with different motorical abilities and techniques, can successfully compete at the top level. It is well known that top high jumpers should be tall, fast, with low body mass and capable of developing the speed of 9 m/s during the last run-up steps.

## THE STUDY SUBJECT AND THE OBJECTIVE

The subject of this study is high jump kinematic parameters. Accordingly, achieving results in top track and field is not possible without analysis of the adequate biomechanical parameters which is nowadays the area of scientific study in the field of sport. We made a conclusion based on numerous researches that it is not possible to reach top results without the adequate analysis of the training process. The objective of the study is to single out model characteristics of competitive activities of high jumpers that are top rated on the world scale, based on the researches done so far and the available literature.

## DISCUSSION

Through the analysis of various researches' data we obtained kinematic parameters of the last steps of run-up and take-off (velocity, knee angles, hip joints angles, centre of mass height and others).
In Fosbery technique, rotation is comprised of 'twist, (rotation around longitudinal axis – body), which turns the jumper's back towards the bar, and 'bridge'

(rotation around the transversal axis), which causes shoulders to move downward and knees upward (Dapena1988). Combination of the two elements creates a position of “twisted bridge”, which creates face up position at the highest jump point. Use of computer modeling and graphic makes it possible to predict approximate maximum height the jumper may clear without touching the bar during the particular jump.
The COM height (table 1) during the flight over the bar depends on the height and vertical velocity of the COM during the take-off (Isolehto and associates 2003). This table shows the COM height at the moment the foot touches the ground during the take-off (H1), take-off (H2), and the COM height at the moment of the highest flight-over-the bar point (H3). These parameters are illustrated the same way in the percentual relation to the body height.

Dapena and associates (1990) discovered a positive relation (r=0.79) between the horizontal velocity at the end of the take-off and vertical COM velocity at the take-off.

*Table 1: Parameters of the best high jumpers’ COM heights*

| Name | H1 (m) | H2 (m) | H3 (m) | Result (m) | H1 % | H2 % | H3% |
|---|---|---|---|---|---|---|---|
| Yuriy Krymarenko | 0.88 | 1.32 | 2.40 | 2.32 | 47.51 | 71.08 | 2.40 |
| Victor Moya | 0.85 | 1.40 | 2.38 | 2.29 | 43.52 | 71.22 | 2.38 |
| Yaroslav Rybakov | 0.99 | 1.43 | 2.32 | 2.29 | 50.56 | 72.96 | 2.32 |
| Mark Boswell | 0.88 | 1.36 | 2.31 | 2.29 | 46.46 | 72.06 | 2.31 |
| Jaroslav Baba | 0.93 | 1.41 | 2.33 | 2.29 | 47.40 | 71.79 | 2.33 |
| Nicola Ciotti | 0.86 | 1.34 | 2.33 | 2.29 | 45.83 | 71.76 | 2.33 |
| Stefan Holm | 0.87 | 1.28 | 2.32 | 2.29 | 48.07 | 70.72 | 2.32 |
| Vyacheslav Voronin | 0.89 | 1.39 | 2.30 | 2.29 | 46.95 | 72.89 | 2.30 |
| Dragutin Topić | 0.99 | 1.34 | 2.31 | 2.25 | 50.30 | 67.92 | 2.31 |
| Kyrikos Iannou | 0.98 | 1.36 | 2.29 | 2.25 | 50.67 | 70.47 | 2.29 |
| Oskari Frosen | 0.97 | 1.42 | 2.29 | 2.20 | 50.05 | 73.40 | 2.29 |
| Matt Hemingway | 0.97 | 1.43 | 2.32 | 2.20 | 49.19 | 72.37 | 2.32 |
| Andriy Sokolovskyy | 0.97 | 1.40 | 2.24 | 2.20 | 49.44 | 71.33 | 2.24 |
| average | 0.93 | 1.37 | 2.32 | 2.27 | 48.15 | 71.54 | 2.32 |
| standard deviation | 0.05 | 0.05 | 0.04 | 0.04 | 2.15 | 1.41 | 0.04 |

In order to provide the complete evaluation of the competitive activities of the athletes, it is necessary to single out the crucial moments which in a complex way characterize level of the special preparedness. Nowadays, these moments are singled out through the factor analysis. This way, six basic factors of moments which characterize kinematic structure of the performance of last steps and take-off were obtained by most authors.

Thus, during performance of high jumps at the heights of 228 – 237 cm the main (leading) factor is the last step. This step is the connection between the run-up and take-off and subsequently the final result depends on the regularity of this step’s performance. Further order of the elements according to their importance is as follows: take-off markers, speed during the take-off phase, speed during the second last step, rhythm, tempo and the speed of the last step.
The crucial differences in high jump techniques at different heights were established as well. The greatest noticeable difference is between the initial and the final jumps. Unlike the jumps at the maximum height, the most important factor with the jumps at the initial heights is the speed during the last step, following according to the level of the importance: performance of the second last step, tempo of the last run-up steps, rhythm of the last run-up steps, take-off and activities (running) in the last step.
The analysis of performed main factors’ technique of the last steps and take-off shows that the biomechanical structure of this part of jump at maximum heights differs from the structure of the last run-up and take-off steps in the jumps at the initial height. Out of six factors only three are characterized by the specific technique at the beginning of the competition and at the end of it as well. Characteristics of the second last step have the leading role at all high jump heights. This is the reason why a special attention must be drawn to this part of run-up at the analysis of jump technique, and also during its improvements at training process.
Some of the markers are also possible to view as model characteristics of top high jumpers’ competitive activities. (Table 2)

**Table 2:** Model Characteristics of Top High Jumpers' Competitive Activities

| Ord. No | MODEL CHARACTERISTICS / UNITS OF MEASUREMENT | NUMERICAL RANGE |
|---|---|---|
| 1. | Time between the touch down and the vertical moment during the second last step, seconds | 0,039 – 0,049 |
| 2. | Touch down time during the second last step, seconds | 0,130 – 0,141 |
| 3. | Time of the second last step, seconds | 0,232 – 0,246 |
| 4. | Touch down time after the vertical momentum during the last step, seconds | 0,115 – 0,121 |
| 5. | Speed of the initial flight phase, m/s | 4,85 – 5,27 |
| 6. | Lower knee angle during the last step, degrees | 59,5 – 63,9 |
| 7. | Angle of the take-off leg knee joint at the moment of amortization during the last step, degrees | 128,0 – 144,0 |
| 8. | Knee joint angle of the non take-off leg at the moment of amortization during the last step, degrees | 47,0 – 56,0 |
| 9. | Angle of the hip joint of the take-off leg at the moment of amortization during the second last step, degrees | 190,0 – 198,0 |
| 10. | Angle of the knee joint of the take-off leg at the moment of landing during the second last step, degrees | 149,6 – 159,6 |
| 11. | Angle of the take-off leg hip joint at the moment of planting for take-off, degrees | 187,0 – 194,0 |
| 12. | Angle of the take-off leg hip joint at the moment of landing during the second last step, degrees | 225,0 – 249,0 |
| 13. | Angle of the take-off leg hip joint at the moment of planting during the last step, degrees | 218,0 – 229,0 |
| 14. | Tempo of the fourth run-up take-off step, step/s | 3,21 – 3,67 |
| 15. | Coefficient of the run-up tempo contrast ( constituent parts ratio ) | 1,41 – 1,89 |
| 16. | Coefficient of the tempo mobilization | 5,98 – 7,98 |

Results of these researches made it possible to define characteristics of competitive activities of high jumpers. Bearing in mind differences in kinematic structure of last run-up and take-off steps at the performance of jumps at various heights, jumps at the sub maximum and maximum heights should be implemented more often during the trainings of high jumpers, and it is necessary to perform the constant control of the kinematic structure of the jump with the high jumps at various heights.

Regularity of high jump performance should be controlled during the training, paying special attention to the main factors of the kinematic structure. Unfortunately, it is still performed visually in the sport practice in our country. A coach needs a specific experience for this. First of all the attention should be paid to the final part of the run-up. It is well known that the final part of the run-up should be performed with acceleration during the last three steps. Only such running creates optimum conditions for performance of a proper take-off. Especial attention should be paid to the second last step, that is, from the take-off leg to non take-off leg. During performance of this move an excessive reduction of angle of planting leg on the ground causes respective extension of time of the first touch down phase (until the vertical momentum). As a result of this mistake a hip joint angle of the off leg increases during the amortization phase, the jumper's body leans backwards, and non take-off leg goes far away at the front and completely stretches at the final moment of touch down. This causes decrease (deceleration) of motion activities during this step and as a result it influences performance of the whole second last step. The step becomes too long and tempo becomes noticeably reduced. It further causes excessive under squat (decrease of the knee angle) during the last step, planting of the leg at the take-off spot and makes it harder to cross the bar, due to great decrease of the jumper's speed it seems that he "stops" above the bar.

Kinematic structure of the jump is also disturbed when a jumper plants a leg on the ground leaning too much during the second last step. The jumper seems to "slide" and "run across" the take-off, path of the body movement (crossing over the bar) is flattened and its highest point is behind the bar.

During such jump there is a fast increase of the second last step which decreases its length. At the final moment of touch down during the second last step, upper leg of the non take-off leg is elevated high, which forces the jumper to put it on the ground during the last step, with the very fast movement (simply "trip it").

## CONCLUSION

Based on the previously presented, it could be concluded that biomechanics in sport is used to prove the main characteristics of moving activities through the development of technique of individual track and field disciplines. It is also used to perfect techniques in order to decrease or avoid injuries, to increase the achievements, develop training process or possibly modify sport technique. This study shows model characteristics of high jumpers' competitive activities such as speed, angles of knee and hip joints and other parameters which are crucial for top quality achievements in high jump. Differences and deviations in cinematic parameters of various researches give us the reason to conclude that there is not one ideal model, that is, technique of flop high jump. Insofar a jumper has characteristics of competitive activities mentioned above, a high quality result in this competing discipline could be expected.

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## MODELNE KARAKTERISTIKE SKAKAČA U VIS ZA VRIJEME TAKMIČENJA

*Originalni naučni rad*


**Sažetak**

Mnogi naučnici su izučavali antropometrijske karakteristike i kinematičke parametre kod skakača uvis. Sprovedeno je dosta istraživanja sa ciljem da se dopune i prošire postojeće informacije. Postignuće u vrhunskoj atletici nije moguće bez praćenja adekvtnih biomehaničkih parametara kojima se danas i bavi nauka u oblasti sporta. Brojna istraživanja nas navode na konstataciju da bez adekvtnog praćenja trenažnog procesa nije moguće dostići vrhunski rezultat. Analizom podataka raznih istraživnja dobijeni su kinematički parametri poslednjih koraka zaleta, odskoka i leta, a to su brzina, uglovi u kolenu, uglovi u karličnom zglobu, visina centra težišta tela i dr. Na osnovu svih navedenih parametara u ovom radu izdvojene su modelne karakteristike takmičarske aktivnosti skakača uvis koji se svrstavaju među deset najboljih skakača proteklih godina.


**Ključne riječi:** skok u vis, biomehanika, ugao, brzina, analiza.


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