BIOMECHANICAL OF KINEMATIC PARAMETERS AT TAKE OFF PHASE IN HIGH JUMP

Dr. ZiadSaleh Ali Swedan

Dr. Fatima Salem Ashsb

Dr. AbirRagabMasoudIssa

1. Introduction

There were no high jumping event in the ancient Greek Olympic Games. But modern high jumping began in Germany in the late 18th Century. It started as a physical education activity for children, and then it developed into a competitive sport in England in the 19th Century and soon, afterward, spread to Canada and to United States (Dapena, 2002).

At the 1968 Olympic Games in Mexico City, Dick Fosbury won the gold medal in the high jump using a revolutionary new technique, which became known as the “Fosbury Flop”. At present, in high jumping the Fosbury Flop is the sole technique used by world-class high jumpers. In general, the high jump can be divided into three parts or phases: run-up (or approach), take-off and flight (or clearance bar) (Dapena, 1996; Isolehto, 2007). The most of all modern high jumpers use the Fosbury Flop technique and the current world records (men: 2.45 m, women: 2.09 m) were set with this technique (Ae, at el, 2008).

However, the jumping events can be divided into two general categories – the vertical jumps (high jump and pole vault) and the horizontal jumps (long jump and triple jump) (Ecker, 1997).

One fact we know is that if a jumper introduced to high jump event, initially learns poor or compromised technique, it will be very difficult for that athlete to eliminate later that technique when attempting personal best heights, even if they later switched to work with a more knowledgeable coach, who corrected their technique.

Initial understanding of the correct mechanics of the high jump and understanding of the event and action - reaction consequence of different movement patterns is extremely important for the athlete to master (Holling&Ritzdorf, 2003).

In addition, the high jump competition is where one´s performance and improved record level depends on many kinematic parameters needed to be studied.

As well as sports biomechanics are used to improve performance by developing techniques and to improve the latest techniques to minimize injuries, to maximize performance, develop exercise mode and, lastly, to modify sport techniques. So, for the long jump, triple jump and high jump, the biomechanical principle will be able to minimize injuries and improve performance (Ismail, 2002).

Most of progressive nations have developed methods in physical education to improve the performance of athletics for better record level by applying scientific research methods and studies in this field. Biomechanics is concerned with the study, analysis of physical movement, and looking for suitable dynamic motions improving the performance of competitors in a particular competition. Biomechanics, as a scientific discipline of kinesiology, studies specific sport movements on the basis of adjective physical, anatomical, and physiological laws. Without doubt, biomechanics is one the fundamental methods for the objective study of special sport motions constantly increasing competition in modern sports – which particularly applies to track and field – calls for increasingly in depth work in the introduction of a new biomechanical technologies and procedures for objective assessments of the technique of movement (Čoh, 2002).

Biomechanics is very important for physical educators, coaches, and other in the business of teaching or analyzing human motion (Simonian,1980).

1.1. The problem of study

The problem of research has risen because of the declining of the jump record level in Egypt is lower than (2.24 m). This country is part from North Africa, this record level is very low compared with the Arabic record level which is (2.34 m) and even much lower than the World record which is (2.45 m). This decline of the Egyptian performance level is due to lack of researches and training in the field of high jump athletics. Thus there is a need for research to study the kinematic parameters affecting the performance of competitors to improve the record levels that are required to become comparable with the world record. However, despite the relatively large number of studies that deal with the high jump event, the researchers were unable to find even one study of the high jump in their faculty in Zawia, which has studied the jumpers in North Africa. Also, they could not find even one study of three dimensional analysis movement of the high jump event in their country.

1.2. The aim

The aim of this study is to determine how the performance of the high jumpers is dependent on the kinematic parameters of take-off phase

1.3.

1.4. Scientific question of study

According to the aim of study, the following question can be put as a study question about high jump event:

How the performance of high jumpers is dependent on the kinematic parameters of take-off phase?

Relative studies

2.1. Biomechanical analysis of the high jump at the 2005 IAAF World Championships in Athletics

The purpose of the study was to determine how the maximum height of the CM “center of mass” during the flight phase is dependent on the kinematic variables of the take-off and update current knowledge about the development and performance of Fosbury Flop technique.

Thirteen male high jumpers (height: 1.92 ± 0.05 m, weight 76.31 ± 8.13 kg) were filmed during their competitive performances in the men’s high jump final during the 2005 IAAF World Championships in Athletics in Helsinki. The best valid jumps from each of the finalists were selected for the further analysis. The mean official result of the finalists was 2.27 ± 0.04 m.

The mean official results (2.27 ± 0.04 m) in this competition were one of the poorest during the history of the track and field World Championships since 1983. On the other hand the mean height of the CM during the highest point of the flight was 2.32 ± 0.04 m and that corresponds well to the earlier studies when only six to eight best jumpers were analyzed. From the technical point of view the competition was interesting, because all different kinds of variations of the Fosbury Flop techniques were used in this final. These variations are power versus speed –flop and different kinds of hand techniques which are; original running arm action (Topic), leading running arm action (Holm), fast double arm action (Krymarenko) and wide double arm action (Baba). The present results show clearly that the vertical velocity and the height of CM at the end of take-off phase together determine the height of the flight ($r=0.75$, $p<0.01$; $r=0.1$, n.s, respectively). Thus, the vertical velocity of the athlete at the end of the take-off phase determines how high the CM will rise after TO "touch off". The most important factor related to the vertical velocity of TO is the low CM position at TD "Touch down" ($r=-0.70$, $p<0.01$).

These results showed that CM height during the TD is related to hand technique more than physique. Topic, who is using original running arm action, had a lowest value of 68 % of the body height compared to the highest values 73% of the jumpers who used wide double arm action. On the one hand,This difference in arm actions refers 0.08 m, if the jumper is 2 m tall. On the other hand, speed floppers like Topic have a shorter take-off time, greater knee angle and higher horizontal velocity during the take-off phase than power floppers. Thus, high knee joint stiffness is crucial for the speed floppers who probably store more elastic energy to the muscle-tendon complex than the power floppers whose take-off is based more on the concentric muscle action. The increased muscle activity of the leg extensors in the braking phase of the contact is also a prerequisite for efficient storage of elastic energy.

It can be concluded that high jumpers with different body types, physical characteristics and performance techniques have good possibilities to compete successfully in the highest level. The different variations of the flop techniques enable the utilization of the best physical capacity of the each individual jumper. Therefore it seems that there is not only one ideal technique to achieve good results.

2.2. Longitudinal follow-up of kinematic parameters in the high jump

The aim of this study was to evaluate the high jump technique of a single subject by determining the influence of kinematic parameters, tracking the changes to the recorded values with changes to the height of the jump and comparing the recorded values with those of other elite high jumpers. The subject of the study was Blanka Vlasic, the Croatian women's record holder. Over a three-year period, her technique development was followed using data on 25 parameters acquired from jumps ranging from 1.80 m to 2.00 m. The values obtained for Vlasic are, for the most part, within the ranges documented for other world-class women high jumpers. Certain parameters for Vlasic changed with the height of the jump, influenced by improvements in her technique and important motor abilities. The authors found that systematic follow – up of the studied kinematic parameters enabled Vlasic to have a fast and rational technique learning process.

From our analysis of kinematic parameters of the approach, take-off and flight phases, as well as the comparison of data with other elite jumpers, it can be concluded that our subject, Blanka Vlasic, is for the most part within the range of the reference data values. The development in the values recorded for certain parameters over the period of this study point to an improvement in technique and a higher level of fitness. The most noticeable are the increases in the approach velocity and vertical take-off velocity, which resulted in the significant increase in take-off angle. Consistent with this, the approach execution was adjusted, which eventually resulted in an optimal bar approach in the later jumps of the series. Maintaining the high position of the body during the preparation for take-off and the take-of it is one of the important features of our subject's technique. The parameter that indicates consistency in maintaining the high position of the body is the knee angle of the take-off leg, which had a lowest amortization value of 144°.

Over the period of this study, our subject's technique of bar crossing became more efficient and some of the jumps were executed with as little as 0.01m difference between the height of the CM and the height of the bar. With improvements in technique and better fitness levels, our subject can achieve further progress in her results. This raises optimism because she is very young, and her current Performance of 2.05 m gives hope for future world-class achievements. Systematic follow-up of the studied kinematic parameters enabled our subject to have a fast and rational technique learning process. Kinematic analysis contributed to easier identification of the positive and negative characteristics of her technique. However, detected errors were systematically corrected during the training process. For certain technique elements, the coaches modified the existing exercises or developed completely new ones in the training process. The necessity for longitudinal follow-up of high jump technique in developing phases as well as in the phases of technique stabilization is absolutely justified.

2.3. Biomechanical analysis of the top three male high jumpers at 2007

The men's high jump at the 2007 IAAF World Championships in Athletics in Osaka was notable for both the high level of results, the first three all achieved2.35 m, and an interesting contrast in jumping techniques. As a part of a large study of the event, the authors produced this interim report on the kinematic analysis of the best jumps of the medal-lists. They cover 1) the motions in the final part of the approach and the take-off phase, 2) performance description using partial heights of CM, 3) take off time, 4) body-lean angle and 5) knee joint angle. Their examination of winner Donald Thomas's technique, variously described as unusual-looking and like a through in basketball, produces the surprising conclusion that, in fact, it is highly effective on account of his double-arm swing, almost vertical body at the take-off, and the highly raised thigh of the swing leg at take-off. Sample of study was 15 finalists in the men's high jump at the 2007 World Championships.

The motions from before the TD of the penultimate stride to the instant of take-off for the best jumps of the three jumpers covered by this report: the left limbs and trunk are depicted in solid lines and the right limbs are shown in broken lines.

Thomas's main feature was the pronounced inward lean, 8.2 . It has been suggested that the use of the hip abductors of the inwardly inclined take off leg is an important factor to enhance the vertical velocity during take-off. Since great ground reaction force, especially vertical component, tends to adduct the take-off leg hip joint, a high jumper has to resist the adduction moment of the ground reaction forces by exerting great hip abduction torque. A strong abduction torque of take-off leg generated by hip abductors can exert great force on the ground, which helps to raise a high jumper vertically. In other words, the inward lean of the body in the initial stage of the take-off phase may have helped to develop great force of the abductors and the ground reaction force and contribute to raising Thomas' body upward. With creative ideas from athletes and coaches, new techniques can emerge from a combination of existing techniques, which excellent athletes then employ in the techniques of Thomas and Ioannou may be a challenging trial in the high jump.

2.4. Biomechanical model of the take-off action in the high jump

The aim of this study was to identify the key dynamic and kinematic parameters of the take-off action in the high jump. The authors studied a single elite athlete (personal record 2.31 m) using a direct measurement method, i.e a force plate, to measure the dynamic parameters and a synchronized 3D vide system to measure the kinematic parameters. They were able to collect and calculate data on 49 variables. Given that study was focused on just one athlete, generalization of the results can only be limited. However, this was a very specific experiment where the result clearly has theoretical and practical value for biomechanical research of high jump technique modeling. Their findings include that the jumper studied developed the highest ground reaction force in the eccentric phase of the take-off. The ground reaction force in the vertical direction exceeded his body weight by 5.6 times. In the concentric phase, the maximum ground reaction force was 9% lower than in the eccentric phase. They were also able to identify large ground reaction forces in the horizontal and lateral directions, which are manifested in extreme loading on the ankle joint of the jumper's take off leg during the take-off action.

The horizontal velocity of the CM during the take-off action is extremely important as it correlates highly with the vertical velocity of the CM at the end of the take-off ($r = 0.79$). Based on this study it is possible to confirm that effectiveness in high jumping largely depends on the take-off action. The take-off action is primarily defined by horizontal velocity of the CM at the start of the take-off and the vertical velocity of CM at the end of take-off as well as by the duration of the take-off phase. In light of result of the dynamic analysis, the jumper studied developed the highest ground reaction force in the eccentric phase of the take-off action. The ground reaction force in vertical direction exceeded his body weight by 5.6 times. In the concentric take off phase, the maximum ground reaction force was 9% lower compared to the eccentric phase. It is also possible to identify large ground reaction forces in the horizontal and lateral directions, which are manifested in extreme loading on the ankle joint of the jumper's take off leg during the take-off action.

2. Methodology

2.1. Method

The researchers have selected the descriptive method – case study because it fits the nature of the problem of study.

2.2. Sample

The sample of study was selected from competitors of the high jump events, representing the Egyptian international athletic team (n=3). Average age of athletes was 22.3 years. All have at least 7 years high jump experience; all are right in good physical health. The sample was selected by deliberate manner for these reasons: they have participated in latest local competitions, they have higher level of performance in Egypt and they have high skill level.

3.3. Tools and Equipment

1. Video cassettes.
2. Two sets of camera tripod.
3. Two analogue cameras (Fastec Imaging 120 Hz).
4. Video recorder.
5. Tool to measure hight.
6. Balance to measure weight.
7. Adhesive paper tape.
8. Cable.
9. Wind velocity meter.
10. Digital timer.
11. Scoring broads.
12. Background broads.
13. Marker for marking check marks.
14. Standard field of high jump event, high jump stands, high jump pits shelter and cross bar.
15. Video cassettes recorder.
16. Personal lab top (Notebook) and motion analysis software (Simi Motion).

3.4. Pilot study

It has focused on the sample of study. The pilot study was done with the help of assistants “some staff members and postgraduate students atZagazig University”, also, with coordinating of the Center for Research and Consultancy Faculty of Physical Education Sports for men, Zagazig University, where it was videotaped in the Track and Field of Athletic Olympic Center in Al maadi.

This pilot study has helped the researcher to understand the fitness of high jumpers, avoid the obstacles that might arise through the basic study, Calibrate the balance and tools to make sure of their validity, ascertain the validity of the cameras, training of the researcher and his assistants on how to use tools and equipment, and ascertain the validity of the place of videotape.

3.5. Basic study

The basic study was in the Track and Field of Athletic Olympic Center in Al maadi, Cairo, in optimal weather conditions, where videotape was done with the help of some researchers who have done asimilar study before. This basic study was divided into:

First Phase (General characteristics, Physical measurement and videotape)

Initially, all athletes filled in the background boards which have details about their personal history, anthropometric “weight and height” included physiological measurement “blood pressure and rate of heart beat during rest”.

Videotape

The cameras were set for data collection to suit a 3-D analysis (three dimensional). Two cameras were placed separately at the starting position of run-up and the take-off position (Figure 1). The cameras were horizontally panned to capture the motion of the last three strides of run up, take-off and bar clearance. The angle between the optical axes of the cameras was 90^{o} and between the cameras and the bar was 45^{o} (Figure 1). The cameras frequency was 120 Hz and the shuttle speed was 1/500s.
The analyzed area of the last three strides and take off point was calibrated with 1 m × 1 m × 1 m reference scaling frame and the calibration was based on eight reference angles. The length of analyzed movement was defined by the “x” axis, the height by the “y” axis and the depth by “z” axis. The Simi Motion Software was used to establish the kinematic parameters of the technique.

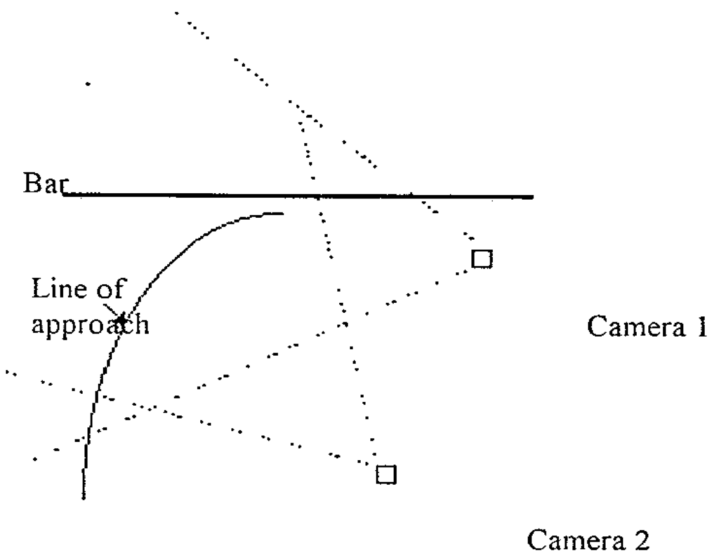


Figure 1: Arrangement and placement of two cameras

Furthermore, only the best attempt of each athlete was analyzed, so the results were applied to the athletes in the sample of study only because the numbers of attempts which were analyzed are small. After videotaping, we were going to focus on:

1. the velocity of CM of the jumper at the run-up phase:

The computer was calculated V through the motion analysis program by measure the distance that CM of the athlete at last three steps in run-up phase then divided it into the spent time.

V = d/t where is d = distant and t = time.

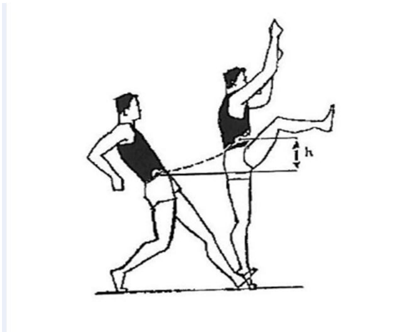
2. time of take-off phase:

The motion analysis program was calculated this time.

3. The peak height from the CM of the jumper until the ground at the flight phase.

4. The velocity of the CM of the jumper at take-off phase:

V_0 = 2h\t where is t = time of take-off phase



(Swedan, 2007)

Figure 2: The difference between the height CM at starting and ending take-off phase.

5. the horizontal and vertical velocities of the CM of the jumper at the flight phase:

We will keep ward advises the velocities of CM in the results and discussion.

Finally, the physical measurement, videotaping and calculating kinematic parameters, collecting data were uploaded in computer program and the following were calculated: The mean errors of the three dimensional coordinates of calibration points were about 0.01 m in the X axis, 0.02 m in the Y axis and 0.01 m in the Z axis, respectively.

4. Results and discussion

As can be seen from many studies results, there are considerable variations in execution of the final stages of the run-up and the take-off at different heights under competitive situations. This strongly accentuates the importance of developing the structure of the final stages of the run-up and the take-off by employing more near-maximal and maximal height jumps in training. Further, it is important to control the kinematic structure of the jumps at different heights. Coaches, who have considerable practical experience and observation capacity, can do this visually. It is commonly known fact that the high jump run-up must be performed with a stressed acceleration of the last three strides. Only this type of the final approach creates optimal possibilities for correct execution of the take-off. The performance of the penultimate stride – the movement from the take-off leg to the lead leg – require particular attention here because it is in this stage that most athletes are bound to make mistakes. The most common fault in this phase of the high jump run-up is the reduction of the angle at which the leg is placed on the surface. An over-reduction of this angle increases the duration of the first part of the support phase (the phase from the start of the support until vertical has been reached). This results in an increased angle in the hip joint of the support leg during the acceleration phase and the athlete’s pelvis is lowered. The straightened lead leg is moved too far ahead at the end of the support phase and the active performance of the penultimate stride drops drastically. The penultimate stride become too long and is performed with considerably reduced velocity. As result the athlete’s CM is lowered during the last stride, the placement of the take-off foot is overemphasized, and the subsequent losses of velocity at take-off reduce bar clearance chances. After such a failed take-off the athlete appears to “hang” in the air. Another typical fault occurs when the athlete places the take-off leg in the penultimate stride with a noticeable forward lean of the trunk. This leads to a “running” take-off with a low trajectory flight phase. The highest point after such faulty execution of penultimate stride is usually reached well behind the bar. The increased velocity of the penultimate stride with a reduced length is responsible for this result. The athlete’s pelvis is lifted higher, forcing, a rapid placement of the take-off leg during the last stride. The jumper simply drops the take-off foot on the surface, which leads to hurried and inefficient take-off action (Jarver,1994).

There are many other factors to be taken into consideration in the final phase of the high jump run-up and take-off. The above discussed kinematic key elements, nevertheless allow control and development of this phase of the high jump with considerable success. As already mentioned, the control can take place visually, although a more objective approach required systematic filming or videotaping of the last run-up stride and the take-off.

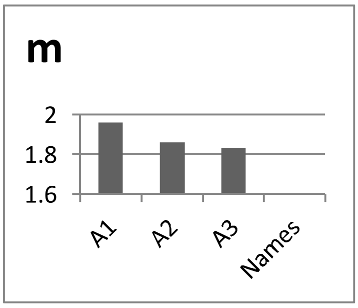
The official results (2.05, 2.02, 2.00 m) in this study are one of poorest in the high jump events. The measurements of the kinematic parameters related to the approach show the poorest parameters. When, comparing the values obtained to earlier studies (Liboshi et al, 1991; Bruggemann&Arampatzis, 1997; Dapena, 2000; Čoh.M&Supej. M, 2008; Isolehto, et al, 2007).

4.1. The physical anthropometric of the high jumpers

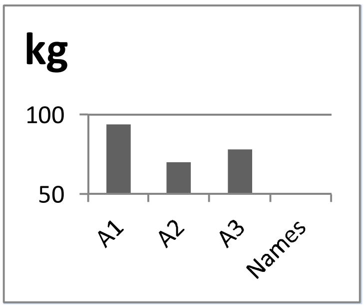
Name of Athlete	Team	Height m	Weight kg	Age	Training Age	The Results m
Athlete (A_1)	Smouha	1.96	94	28	8	2.05
Athlete (A_2)	Al maadi	1.85	70	17	4	2.02
Athlete (A_3)	Police Union	1.83	78	22	7	2.00
Average		1.88	80.66	22.33	6.33	2.03

Table (1): The physical characteristics of the Egyptian high jumpers

Height

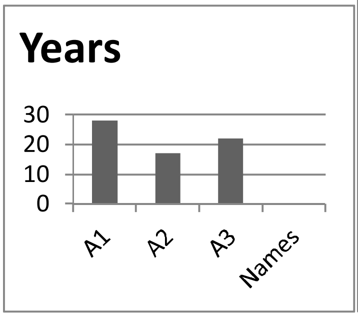


Weight



Age

Results



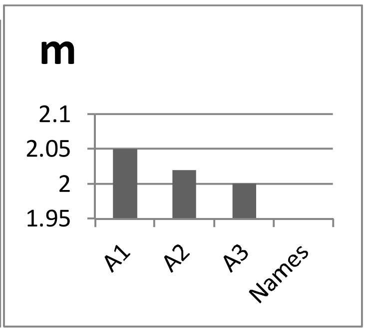


Figure 4: Chart of the physical characteristics of the Egyptian high jumpers

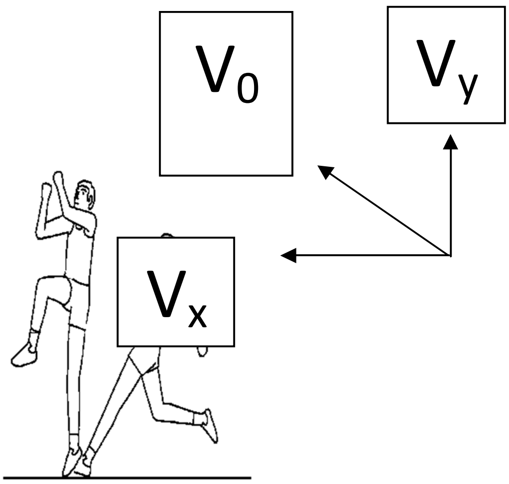
From figure 4 and table (1) show three male high jumpers of study (height: 1.96, 1.85, 1.83 m; weight: 94, 70, 78 kg) were filmed, the physical characteristics of jumpers are presented in Table (1). The official results were (2.05, 2.02, 2.00 m), based on the parameters of three dimensional kinematic analyses (Čoh.M&Supej. M ,2008, table 1,2,3), we can establish that the jumpers are representative of the power-Flop model of high jump technique. Their anthropometric characteristics are not similar to modern model of elite high jumpers, such defined by (Isolehto, et al, 2007) based on data on finalists at the 2005 World Championship in Athletics (Čoh.M&Supej. M ,2008, table 1,2,3)

The body height and the body mass as the general anthropometric dimensions thus point to a high potential of the respective high jumpers on the basis of which top result can be expected. Besides the body height, paramount importance for the execution of the jump technique has the relationship between the body height and leg length. The length of legs defines the initial height of CM and thus the second reference point (the height of the CM at the moment of take-off) of the high jump technique. At the individual level we can establish that in the high jumpers the winner was the jumper Athlete (A_1) who was the tallest with in the subsample as regards the body height (1.96 m). On the basis of what we have said, may conclude that top results are achieved by high jumper of various anthropometric constitutions despite the fact that sample is relatively homogenous as regards the longitudinal dimensions. The difference between the shortest and tallest high jumper is 0.13 m. On a representative sample of Egyptian of high jumpers we have carried out measurements of 2 anthropometric parameters and have thus establish the model characteristics of the anthropometric space that provides import information for the selection and process of training of Egyptian competitors in high jumping. In all the jumping events in track and field, there is a direct correlation between the execution of the run-up, take-off and the performance of a jump.

The more consistent and more technically correct the run-up and take-off, the better jump performance. Most world record performance in the jumping events in track and field, have been a direct result of a successful run-up and take-off. According to mechanical laws, the height of a high jumper depends on three reference points, the height of CM in phase of planting the take-off leg; the height of CM in the take-off phase, and the maximal height of the CM in the flight phase of the high jumper (Dapena, 1992). In addition to the mechanical aspect, the importance of theanthropometricdimensions manifests also in connection with motor abilities, especially in the production of the ground reaction force in the take-off; in coordination abilities, and in the execution of typical movement patterns. Anthropometriccharacteristics are, however, also important in the process of selecting young high jumpers. Optimal constitutional characteristics are a prerequisite for successful competition performance of high jumpers (Conrad &Ritzdorf, 1990). Therefore, this fact must be taken into account both in process of training and in the process of initial selection of potential subjects. In order to establish what is the optimal model of the morphological characteristics in high jumper. We have carried out measurements of the morphological status of the best male and female high jumpers participating at the Athletic Championships. Hypothetically, we can expect, irrespective of the differences in the biological development, similar morphological characteristics as are characteristic of top male and female high jumpers. Therefore, the majority of coaching time in the high jump should be pent developing a technically sound run-up and take-off rather than spending time teaching techniques over the bar. It must be noted that when high jumper breaks contact with the ground, the CM forms a parabolic curve. Once in the air, there is nothing that can be done to change this predetermined flight path. The purpose of this paragraph is to know how the take-off phase is important in high jump event which lend us to talk about important factors in this phase, the velocities.

4.2.The CM velocities of take-off action of high jumpers

Velocity is defined as displacement per until of time, and having both magnitude and direction, it is a vector quantity. In high jumping the athlete’s run-up is not nearly as fast as that of the long jumper, for the obvious reason that a radical change in direction must be made at take-off, which would not be possible at high speeds. The long jumper seeks maximum horizontal distance where the high jumper needs only enough horizontal velocity to carry the body past the bar after it has been cleared. Maximum efficiency is demonstrated when the jumper’s CM is raised no higher than necessary to clear the bar. This is enhanced by the lifting of the arms and the free leg before ground contact is broken so that the jumper's CM is as high as it can be before take-off. In Fusbary flop, a long final run-up step allows the longest possible ground contact time during which to apply a vertical force, which is to convert the horizontal velocity to a vertical velocity (Simonian, 1980).



(Swedan, 2007)

Figure 5: Horizontal and vertical velocity components during take-off

Jumpers / Kinematic parameters	Unit	Athlete (A_1)	Athlete (A_2)	Athlete (A_3)
Horizontal velocity of CM at start take-off (V_{x1})	$m.s^{-1}$	4.16	4.27	4.36
Vertical velocity of CM at start take-off (V_{y1})	$m.s^{-1}$	-0.08	-0.20	-0.35
Horizontal velocity of CM at end take-off (V_{x2})	$m.s^{-1}$	2.08	2.10	2.49
Vertical velocity of CM at end take-off (V_{y2})	$m.s^{-1}$	4.85	3.96	3.71

Table (2): CM velocities of take-off action of the Egyptian high jumpers

When the high jumper leaves the ground and is free in the air, the combination of forward – upward velocity when he leaves the ground and the force of gravity cause his CM to follow a parabolic curve. The depth of the curve (the distance from take-off to landing) is largely determined by the jumper's horizontal velocity at take-off; the height is determined entirely by his vertical velocity at take-off (Ecker, 1996).

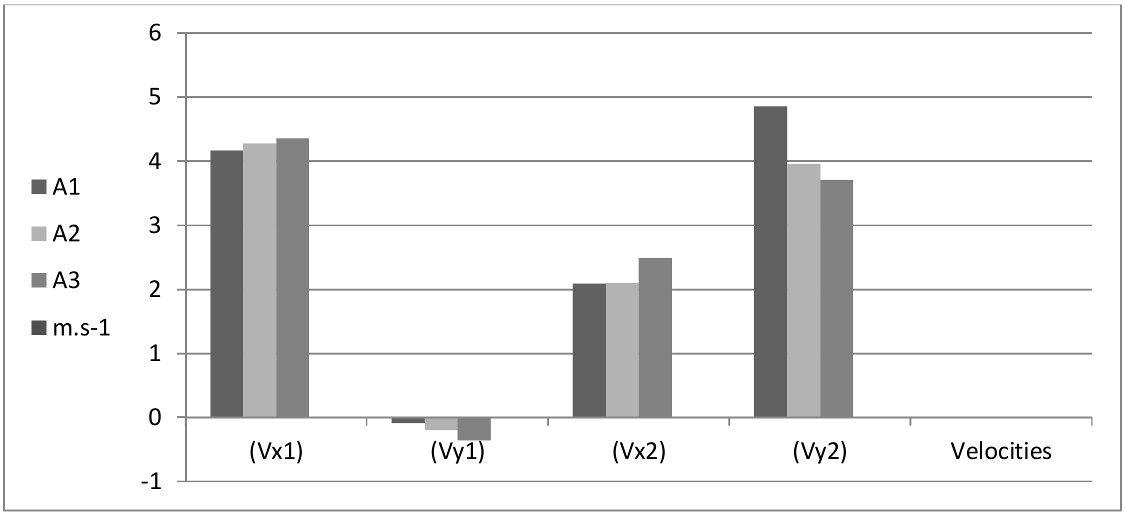


Figure 6: Chart of CM velocities of take-off action of the Egyptian high jumpers

Horizontal and vertical velocity components, Figure 6 shows the typical chart of velocity components at two points, start take-off phase and end take-off phase of the three jumpers. At start take off phase, the horizontal and vertical velocities (V_{x1}, V_{y1}) values were:

Velocities / Athletes	horizontal velocity (V_{x1}) $m.s^{-1}$	vertical velocity (V_{y1}) $m.s^{-1}$
Athlete (A_1)	4.16	-0.08
Athlete (A_2)	4.27	-0.203
Athlete (A_3)	4.36	-0.35

In high jump, movement from the ground is the result of ground reaction forces that are equal and opposite to the forces applied against the ground. The greater the forces applied to the ground, the greater the forces returned to the jumper. The jumper's horizontal velocity at take-off is result of a series of horizontal ground reaction forces during the acceleration portion of the run-up. The vertical velocity results from the forces applied to ground during take-off (Ecker, 1996). The high jump requires more vertical than horizontal velocity (although very little more, since high jump take-off angles are seldom much greater than 45º degrees), and, of course, the take-off is higher. Each CM of jumper follows a perfect parabolic curve (except for the minimal effects of air resistance) once the jumper is free in the air. High jumpers, the curve is shorter and much higher.

At the end take off phase, the horizontal velocities (V_{x2}) were decreased to:

Athletes	horizontal velocity (V_{x1}) m.s^{-1}
Athlete (A_1)	2.08
Athlete (A_2)	2.10
Athlete (A_3)	2.49

And the vertical velocities (V_{y2}) were increased up to:

Athletes	vertical velocity (V_{y1}) m.s^{-1}
Athlete (A_1)	4.85
Athlete (A_2)	3.96
Athlete (A_3)	3.70

Table (4), summarizes the values of the velocity components at this critical phase of the high jump. The Egyptian high jumper's horizontal velocities of CM at start take-off (V_{x1}) were very slow when compared to what were seen in the jumpers in the World Championship. In addition, the high jumpers of the sample are likely that they accelerated their horizontal velocity of CM at start take-off (V_{x1}) as:

Athletes \ Velocities	From m.s^{-1}	To m.s^{-1}
Athlete (A_1)	4.16	2.08
Athlete (A_2)	4.27	2.10
Athlete (A_3)	4.36	2.49

Where, most high jumpers tend to decrease the CM velocity in order to prepare for take-off phase.

Throughout the take-off, the jumper accelerates the arms and free leg upward, so that all are high when the take-off foot leaves the ground. Because the arms and free leg are swinging upward while the take-off foot is pushing downward against the ground, the result is a great increase in force applied to the ground, and in the force the ground returns to the jumper. The result is increased vertical velocity at take-off.

Furthermore, the execution of penultimate support sets the pattern for the last run-up stride. At this stage a pre-tensed take-off leg moves down and back, as the hip-trunk angle on the side of take-off increases. At the same time the relative velocity between the ground and take-off foot is reduced. The take-off foot reaches the last support phase heel first, or is placed on the whole sole of the foot. It strikes the ground actively, so that the contact between the sole of the shoe and surface can be often observed acoustically. Provided the necessary muscular pre-tension is held at the take-off leg side, the bending in the joints can be compensated for relatively quickly to efficiently exploit the lever function of the take-off leg.

The longitudinal axis of the take-off foot should in the last stride be in line with the projected flight path of the CM. This will insure that the forces are correctly transferred into the take-off action and the negative transverse forces are largely eliminated. A fast contact with the surface allows the possibility for the extensor muscles of the participating joints to check immediately any further bending in order to start early the directional change of CM horizontal to vertical. The existing inward lean of the athlete prior to take-off is important for an effective performance of the take-off. Equally important is an immediate formation of leg-trunk angle in order to avoid a forward bend in the upper body during the last stride. This applies to all variations of the lead- leg action in the flop technique and is best achieved by the earlier-described hip movement to open the leg-trunk angle. The inward lean and the trunk angle are responsible for the establishment of the so-called take-off layout. It is significant that the knee of the take-off leg has at this phase not yet reached the vertical position above the support point. The inward lean should be at start of take-off action around 70 to 85º, the trunk angle ranges from 85 to 125º. The larger angles are typical for male high jumpers (Jarver, 1994).

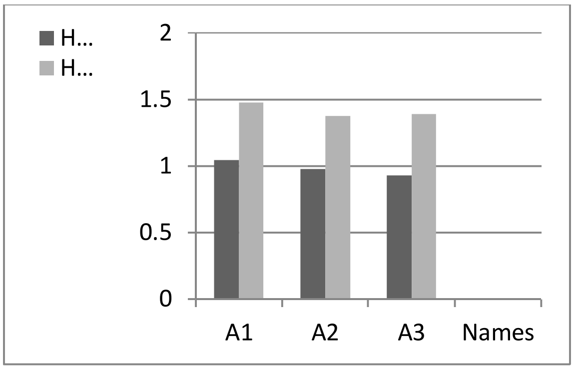
4.3. The height of CM and take-off time of high jumpers

Theoretically this ought to be at its maximum so that contact with the ground is lost as CM passes over the supporting foot, this never happens. The faster the run-up the more likely the CM is to be in front of the support foot and thus lower than it could be. This is especially true of long and triple jumpers. Of course, physique comes into it too. A tall high jumper has an advantage, as do tall athletes in most events, providing the physique is equal to the other demands of the event. All movements which raise limbs at take-off raise the CM also. So a fully extended and raised lead leg, a high upward thrust of the free thigh and arms well raised up are assisting in this direction. In high jump event, a jumper tries to have his CM as high as possible at the take-off and directly over his jumping foot. It is never, which is just as well because the eccentric thrust that result is needed for some of the rotations which move him into the layout position in the air. The novice, however, gains his rotation at expense of height, typically leaning towards the bar, thus both lowering his CM and creating the condition for a sideways jump (Jarver, 1994).

Jumpers / Kinematic parameters	Unit	Athlete (A_1)	Athlete (A_2)	Athlete (A_3)
Height of CM at start of take-off (H_1)	m	1.04	0.97	0.92
Height of CM at end take off (H_2)	m	1.47	1.37	1.38

Take off time (T)	s	0.160	0.152	0.176

Table (3) the height of CM and take-off time of the Egyptian high jumpers



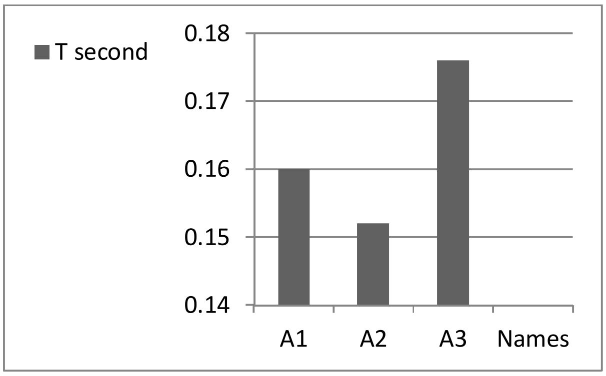


Figure 7: Chart of the height of CM and take-off time of the Egyptian high jumpers

The values of the partial heights of the CM of Egyptian jumpers at two points, start take off phase and end take-off phase were (1.04 m,0.97 m, 0.92 m and 1.47 m, 1.37 m, 1.38 m respectively), which are lesser than the partial height of high jumpers at World Championships in Athletics. Also, the value of take-off time of the Egyptian high jumpers were (0.160 s, 0.152 s, 0.176 s respectively), which is lesser than take-off time of high jumpers at World Championships in Athletics. (Dapena, 2006; Isolehto, et al, 2007; Čoh&Supej, 2008) found the one of the key parameters that directly influences jump height is position of the CM at the end of take-off phase (H_2). The maximum height of the CM at the end take-off phase largely depends on the jumper's anthropometric characteristics (body height) and take-off technique. The partial change in the CM in take-off action is mainly related to the transformation of the horizontal velocity into vertical velocity of the CM during the take-off phase (Hay, 1993).

Of the three factors which contribute to successful high jumping, the distance CM can be lifted from take-off to peak of the jump (the result of a good take-off) is by far the most important. However, the height of CM at take-off actually contributes the most to the jump – about two thirds among experienced jumpers – but that factor is entirely dependent upon the jumper's natural physique and the position of his arms and free leg at take-off (Ecker, 1996). The approach run takes the jumper to the point of take-off, allows him to assume the take-off position, and establishes the horizontal velocity for jumper's flight path after take-off. The length of the approach is usually dependent upon the ability of individual jumper. The beginner, who does not require as much approach speed as a seasoned jumper, should use a shorter run-up 6 to 8 strides. The veteran jumper may use as many as 12. Although some jumpers have attempted straight approaches to the crossbar, it has been shown that a curved approach requires the jumper to lean into the curve, which offsets the otherwise natural tendency to lean toward the bar at take-off. This insures a more vertical take-off, and produces additional force against the ground.

Some studies showed that the CM height during the start of the take-off phase (H_1) is related to arm technique more than physique. The jumpers who used the normal running arm action had lowest value, 68% of body height, compared to the highest values 73% of the jumpers who used the wide double arm action. This difference due to arm action can be (0.08 m), if the jumper 2 m tall (Liboshi, et al, 1993).

The Egyptian high jumper's take off time were (0.160 s, 0.152 s, 0.176 s respectively). The duration of take-off phase depends on the knee angles at the instant of touchdown and take-off as well as the knee angle at instant of maximum amortization. The take-off time is not a reliable criterion of a good or poor technique. It is no significantly correlated with the result of the high jump (Dapean, 1990). However, it is a valid criterion for assessing the speed-flop and power-flop techniques. The jumpers whose take off time is short belong to the group of speed-floppers and those with long take off time to power-flopper, whereas, the entire take off time phase lasts from 0.14 to 0.18 of second (Dapena, 2006; Čoh.M&Supej. M.,2008).

5. Conclusion

Within the limit of research sample, in view of data collections, the results interpretations, analysis motion by computer and videography the following conclusions were achieved: there is relation between record level and vertical velocity component (V_y). Also, there is relation between each of following: take-off time and height projection, take-off time and the vertical velocity component (V_y).It is also, the hypotheses of research and expectations of researcher have been achieved, that means that the aim of the research was achieved and accessible. Looking at the value of horizontal and vertical velocity at start and end of take-off phase, height of CM at start and end of take-off phase and take-off time, we can see the different of the values of kinematic parameters between the Egyptian high jumpers and elite high jumpers; this is what the researcher expected to occur. On the other side, when we look at the results of the Egyptian high jumpers A_1, A_3 we can see the different of the values of some kinematic parameters for each one; this what the researcher expected before.

Based on this study it is possible to confirm that effectiveness in high jumping largely depends on the take-off action. The take-off action is primarily defined by the horizontal velocity of CM at the start of take-off phase and the vertical velocity of the CM at the end of the take-off phase as well as by duration of the take-off phase. Also, it can be concluded that different variations of the flop technique enable the utilization of the best physical capacity of each individual jumper. Therefore, it seems that there is not a single, ideal technique for achieving good results and jumpers with different body type, physical characteristics and performance techniques have good possibilities to compete successfully at the highest level. Looking at both the horizontal and vertical velocities, it is seen that as the height of the bar increases both the horizontal velocity and the vertical velocity of the jumper increase. This is what we expected to occur since it would seem unusual for a jumper to have the same horizontal and vertical velocities for different heights. With improvement in technique and better fitness levels, our jumpers can achieve further progress in their results. This raises optimism because Omar Samir (A_2) is very young, and his current record is 2.02 m gives hope for future World – class. Systematic follow-up of studied kinematic parameters enabled our jumpers to have a fast and rational technique learning process. Kinematic analysis contributed to easier identification the positive and negative characteristics of their technique. In this way, detected errors were systematically corrected during the training process. For certain technique elements, the coaches modified the existing exercises or developed completely new ones in the training process. finally, the performance of high level in the high jump is not necessary to depend on technique and training only, but there are several other factors such as social, psychological and health factors.

6. Recommendations

According to the results obtained, the researchers recommend the following: continuous training of the specimen competitors particularly competitor (A_2), in course of training of competitors for high jump event attention should be concentrated to vertical velocity component (V_y) for CM of body athlete with minimum take-off time, choosing tall competitors for high jump event as they will have large height of CM which will lead to better record levels, using methods of videotaping in three dimensions in biomechanical analysis of data, results and conclusions should be compared with other studies for better applications. Also, it is critical that the jumper stay relaxed and maintain run-up speed through the last two strides. When using a double arms action, it is important that jumper move through the arms and not stop them. Stopping the arms over the last two strides will result in decrease in run-up speed to the bar. Thus, it is important that arms move to fit the run-up. It is important that the athlete time up the momentum of the free leg and arms at the take-off phase. As the jumper leaves the ground, the eyes should no longer be focused on the crossbar. At this point, the eyes and head should follow in natural alignment with the transverse rotation of shoulders. The more inexperienced the jumper is, the closer the take-off point should be. The more experienced the jumper, the father away the take-off point should be. Factors influencing this take-off point will depend on the athlete's experience, speed and strength.

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ملخص البحث

العنوان : دراسة بعض المتغيرات الكنيماتيكية خلال مرحلة الارتقاء في مسابقة الوثب العالي.

الهدف : تحديد تأثير بعض المتغيرات الكنيماتيكية على مستوى الإنجاز للمتسابقين في مسابقة الوثب العالي.

المنهج : المنهج الوصفي – دراسة الحالة مستخدماً التحليل الحركي بالتصوير الثلاثي الأبعاد.

العينة : اختار الباحث العينة بالطريقة العمدية من الفريق الوطني للألعاب القوى بجمهورية مصر العربية وكان عددها ثلاثة متسابقين.

أهم النتائج :

1- وجود علاقة ارتباط بين مستوى الإنجاز الرقمي للمتسابقين ومركبة السرعة العمودية لكل متسابق.

2- مرحلة الارتقاء بمسابقة الوثب العالي له الأثر الأكبر على مستوى الإنجاز للمتسابقين.