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Faculty of Physical Education and Sport

Dissertation thesis presented by

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Title

THE RELATIONSHIP BETWEEN SOME KINEMATIC PARAMETERS WITH THE PERFORMANCE LEVEL OF EGYPTIAN HIGH JUMPERS

Under the supervision of

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At first, I would like to pray to my God for ending this study.

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Ziad Swedan

Abstract

The aim of this study was to determine how the performance of the Egyptian high jumpers is depending on the kinematic parameters of a take-off phase. The sample of the study has been selected from competitors of the high jump event - three jumpers representing the Egyptian international athletic team. The researcher has studied the sample using a direct measurement by a synchronized 3D video system to measure the kinematic parameters. The researcher has found a relation between record level and vertical velocity components with improvement in technique and better fitness levels, thus the Egyptian jumpers can achieve further progress in their results. This raises optimism because Omer Samir (A_2) is very young and his current record 2.02m gives hope for future World – Class.

Key words

High jump, kinematic parameters, take-off phase.

Souhrn

Cílem studie bylo porovnat vztah mezi výkonností ve skoku vysokém a kinematickými parametry odrazové fáze u egyptských skokanů do výšky. Vzorek probandů byl vybrán ze skokanů národního egyptského týmu.

Výzkum byl realizován pomocí přímého měření synchronizovaného 3D video systému pro indikaci kinematických parametrů.

Výzkum ukázal vztah mezi rekordní úrovní a vertikální složkou rychlosti, který predikuje v případě zlepšení techniky a úrovně speciální kondice, možnosti dalšího rozvoje výkonnosti egyptských závodníků. Tento nárůst je předpokládán především u Omer Samir, který je velmi mladý a jeho současný rekord 2.02 m mu dává naději na budoucí výkonnost v širší světové špičce.

Klíčová slova:

skok vysoký, kinematické parametry, odrazová fáze skoku.

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Contents

1. Introduction

There was no high jumping event in the ancient Greek Olympic Games. This sport event seems to have its origin at the Celts (Tailteann 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). The next technique in the evolution of high jumping was the "scissors", in which the legs are lifted over the bar in alternation one after the other. The advantage of the scissors technique is that parts of both legs are below the level of the bar at the peak of the jump. (Dapena, 2002). The scissors has been followed by the "Eastern cut-off'" technique (in Europe sometimes called the "Lewden scissors"). In the Eastern cut-off the athlete rotates the trunk into a horizontal position at the peak of the jump. The Eastern cut-off was succeeded by the "Western roll" technique. In the Western roll the athlete cleared the bar on his/her side, with the take-off leg tucked under the rest of the body. The Western roll was followed by the "straddle" technique. In the straddle the athlete cleared the bar face-down. The Eastern cut-off technique with the body stretched along the bar (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,1981)

2. Literature review

2.1. Structure of sport performance in high jump event

Sport scientists have examined numerous factors influencing the acquisition and manifestation of high levels of performance. These factors can be divided into variables having a primary influence on expertise and variables that have a secondary influence through their interaction with other variables.

Performance demands in present day peak sports increase continuously and only individuals, with whom factors influencing performance are on a high level, can expect to succeed (Langer, 2007).

(Rienzi, 2000; Kopecký & Přidalová, 2001; Langer, 2007) state that sports performance is determined in a differential way by somatic, functional, psychological and motor characteristics and capabilities.

In general, the main factors of individual sport performance are five factors which are somatic, technical, tactical, personality and level of fitness; however, if we want to improve the performance of any individual sport as well as the high jump event, we must be aware of these factors. This study will focus on the factors of the performance of the high jump event.

After all, sport performance is determined by a different number and structure of factors. To know more about these structures, we should answer the following questions:

- On which factors is the sport performance depending on?
- What are these factors and what is their nature?
- How are these factors important for the performance?
- What are the relations among factors?
- Are they dependent or independent?

However, in these paragraphs, we will try to answer the first question. One of the key parameters that directly influences the jump height is the position of the CM at the end of take-off phase. The maximum height of CM at the end of the take-off phase largely depends on the jumper's anthropometric characteristics (body height) and take off technique (efficient extension in ankle, knee, hip joints and the trunk) (Čoh & Supej, 2008). In other words, the performance (jump height) is depending on two main factors: 1. somatic (the height of CM at the end of the take-off phase which depends on the body height of the jumper), 2. Technique and tactical (efficient extension in the joints of the body).

2.1.1. The somatic (physical patterns)

Specific anthropometric characteristics are needed to be successful in certain sporting events. It is also important to note that there are some differences in body structure and composition of sports persons involved in individual and team sports. The tasks in some events, such as shot put or high jump, are quite specific and different from each other and so are the successful physiques. This process whereby the physical demands of a sport lead to selection of body types best suited to that sport is known as "morphological optimization" (Abraham, 2010).

The physique becomes a limiting factor of performance, i. e. a direct reflection of the level of movement activities. This knowledge is of great importance when suitable types for various sports branches or events are sought (Rienzi, 2000; Kopecký & Přidalová, 2001; Langer, 2007).

Also, (Langer, 2004 & 2007) kept under review age regularities of the development of biomechanical parameters in the run up and the take-off technique in the context of changes of anthropometric character.

This is also an important indicator of choosing high jump athletes. High jump athletes requires high physique, light weight, lower limb length, width of body, physically smaller, a rob shaped buttocks muscle, long tendon, Zugong height, short toe and trim and the flexible sole of foot.

1 – Height： more athletes using the Fosbury Flop have broken world records twelve times. eight athletes average Height is 1.97 m, Women is 1.80 m. According

to the experience of most coaches, the ideal height of males is over 1.95 meters, and for females is over 1.78 meters.

Name	Gender	Country	Height （m）	Weight （kg）	Best results （m）
Sotomayor	male	Cuban	1.95	82	2.45
Sjǒberg	male	Sweden	2.00	82	2.42
Paklin	male	Soviet Union	1.91	70	2.41
Povarmitsgn	male	Soviet Union	2.01	82	2.40
Austin	male	USA	1.88	70	2.40
Zhu Jianhua	male	China	1.93	70	2.39
Kostadinova	Female	Bulgaria	1.80	60	2.09
Vlašič	female	Croatia	1.93	75	2.08

Table (1): World outstanding high jump athlete's stands (Guangye, et al,2006)

We can see that the world's outstanding high jump athletes have tall physiques. Sotomayor the world men´s record holder is 1.95 m high. He has long fast legs, strong firms, good flexibility for a reasonable run and ground take-off and a rare high jump talent. In the women's high jump projects the World Champion Kostadinova who is from Bulgaria, has reached the height of 1.81 m, she is tall and has a very good build, especially her long pair of thin and strong legs. Some coaches have said that her legs are the "most beautiful and most powerful legs in the world". In accordance with the different stages of growth characteristics, not only their existing height, but also we should consider its future potential. If height is less than ideal height, on land we can consider that power, speed, flexibility and quality can serve as a target to improve their performance.

2- Weight: the table shows the weight in kilograms, it is a reflection of the important patterns of human development, affected by age, gender, human growth and development of ethnic differences (Guangye, et al, 2006).

2.1.2. Personality (psychological issues)

Due to the nature of the sport, mental preparation is a key element for success in high jump competitions. (Shunk, 2010) While there are limited published articles related to the psychological environment of high jump competitions, some conclusions can be drawn from research in similar fields. When a comparison was made between track events and field events, one study suggested that mental training plays a larger role in outcomes for field events than in track 7 events. In addition, field athletes tend to use visualization more frequently and had strong physical sensations associated with imagery. This could be due to the breaks during field events which allow for more opportunities to stop and focus on imagery. (Ungerleider, 2005) The mental focus during these breaks can play a crucial role as it is an opportunity for the mind to wander. A golf study demonstrated that the professional players were able to refocus on the task after a break between shots much better than inexperienced players (Thomas & Fogarty, 1997).

In athletics, there are great differences between the high jump and other events with respect to time, space and the rules of competition. Because of these differences, the psychological characteristics of high jumpers, which are also different from those of competitors in other events, have more impact on performance, especially in high-level competitions. In fact, the psychological state of elite high jumpers usually determines success or failure in major competitions. Therefore, to improve the standard of high jump in any country, it is of great practical importance for high jumpers to master both the psychological characteristics of the event and self-adjustment methods (Ling, 1989).

Special mental quality, special psychological campaigns not only regulate and control but also play a lead rod in a race. Good physical and psychological qualities are that is flexible prerequisite skills can. High jump athlete’s nervous system is flexible particularly that response moving faster show out feel good space identity, orientation ability, a strong initiative, the quality of indomitable will, good ability to control competition, good at using coaches tactical implementation arrangements. These capabilities embodied mainly rely on the athletes to complete a psychological quality, the special mental qualities of the training of athletes are not ignored, emphasis must be places together (Guangye, et al, 2006).

The high jump, especially at high level, is more visible and the time of competition is longer than most other events in athletics. The competition process is relatively complicated as each jumper makes a number of attempts and can pass freely. A high jumper has a greater chance of experiencing negative psychological states during the competition than most other athletes. Psychological states, physical strength and skill influence each other. Because coaches cannot give advice during the competition it is very import ant for jumpers to be able to take measures themselves to overcome any negative psychological states they may encounter (Ling, 1989).

Finally, (Shunk, 2010) has made several suggestions in terms of what high jumpers should focus on. Goals set in high jump should be process oriented rather than outcome oriented as the athletes have very little control over their rank for an event. Also, since it is such a technical sport, most of the goals should relate to technique. Furthermore, Shunk stresses the importance of routines. One reason why high jumpers choke during big competitions is because they view and approach them differently from previous competitions. It is important to create a clear plan and routine to be used in all competitions. Moreover, pre-jump routines are also important to help block out distractions such as simultaneous running events (IAAF, 2002). Overall, it is crucial to be prepared, both, mentally and physically for the challenges posed by a high jump event.

2.1.3. Level of fitness (physical capacity)

With physical preparation for any sport, it is crucial to develop the relevant fitness components needed for competition. High jump is a sport which requires a powerful lower body.

The emphasis in the development of the physical capacities of a high jumper is on the improvement of jumping power. The main components of jumping power are strength and speed and these two components, combined with the correct flight angle, determine the efficiency of the take-off. Strength and speed are developed in parallel, involving all types of jumping exercises under different conditions with different loads and with different tasks.

Also (Baurne, 1992) added that high jump competitions are commonly won or lost with only one or two percent differences by the performance capacities of the competitors. The optimal development of muscular strength and transfer of this to the performance situation is therefore a crucial factor in the training of successful high jumpers. In this event, where the athlete encounters peak forces of between 5-8 times their own body weights on one leg during the take-off, the structural and functional capacities of the musculo-tendinous and neuromuscular systems require optimal development.

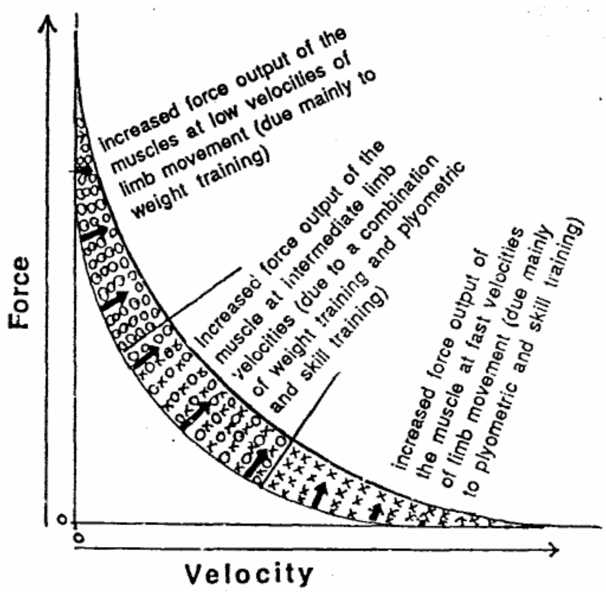
We need a good working knowledge of strength development theory and practice in order the athletes may capitalize fully on the performance benefits offered through strength development programs. Ensuring an optimal transfer to performance of strength gained through supplementary programs requires careful attention to each of the facets of “applied strength” development.

Jumping and bounding exercises can be performed in single efforts, with recoveries, or a series of jumps. The performance can be from a standing position or on the move. The take-off can be from one leg or both legs, the jumps can be on one level, upwards from the take-off level or down from the level. Weight training and exercise machines are used to develop strength of the leg, abdominal and other muscle groups, but the most efficient strength development method is depth jumping with additional weight. Most useful in the development of speed capacities are repetition jumps for distance or against the clock (Portno, 1983).

Also, the vertical velocity at the end of a take-off phase is the key generator of the jump height. To maximize vertical velocity at the end of the take-off, the horizontal velocity of the C.M at the start of the take-off phase is very important as it must be as great as possible (Dapena, 2006). That means level of fitness (the vertical velocity which is depended on the power because the power is composed of force and velocity, in formula P = F x V) is very important to get great jump height (the performance). According to some studies (Dapena, 2006; Isolehto, et al, 2007; Ae, et al, 2008; Čoh & Supej, 2008) the vertical velocity of elite high jumpers at the end of a take-off phase is 3.8 to 5.0 $m.s^{-1}$. Also, during take-off action, the horizontal component of velocity of jumper's CM decreased by 4.45 $m.s^{-1}$and the vertical component increased by 4.16 $m.s^{-1}$. Based on this decrease in horizontal velocity in the take-off action, it can be established that the change is extreme. With elite jumpers, the decrease in velocity equals 3.47 ± 0.28 $m.s^{-1}$.

High jump is a cyclical sport that ends in an explosive take-off and a relaxed flight phase. Power development of the legs is very important in high jump and as a result, and is often the focus of physical training. The aim is to increase explosive strength and power with as little hypertrophy as possible as excess body weight is detrimental to lifting one's center of gravity. An increase of one kilogram in weight can decrease the height of a jump by as much as five centimeters, given other variables remain constant (Aura, 1984).

High jumpers spend many hours in the gym weight training to achieve these results. In addition, explosive-ballistic strength training and plyometric exercises are used to help the athlete pounce forcefully upward at take-off.



The typical theoretical force-velocity curve reveals maximum force output by the muscle at varying speeds of movement. Arrows and shading suggest the ways in which different methods of strength training may be used to modify the performance of the muscle.

Figure 1: Typical theoretical force-velocity curve (Aura, 1984.)

2.1.4. The technique and tactics

The sport of high jump, like other sports, has both technical and tactical aspects to the sport. Due to the nature of the sport, the technical requirements tend to outweigh the tactical side. Tactical preparation refers to the development of a competition strategy, which includes gathering strategic knowledge. Technical preparation refers to effectively acquiring the skills needed for optimal performance (Blumenstein, et al, 2007).

The technical requirements are much more important and complex than the tactical needs. The execution of a jump can be broken down into three different phases: approach or run-up, take-off and flight (Jacoby & Farely, 1995). Possibly the most important and technically challenging phase is the approach phase. An effective approach includes proper speed, the correct angular momentum and the correct hip height. It is the curved path of the run that causes many technical challenges;

this is why up to 90% of the technical focuses on the run-up technique. While the flight phase is an important part of the execution, the actual flight path is set the moment the athlete leaves the ground. The next phase is the take-off phase, when the switch from horizontal movement to vertical movement occurs. From a technical perspective, it is important that the body posture is aligned correctly, and that the jumper rotates forward and laterally because this rotation causes the body to propel over the bar. Finally, in the flight phase the athlete follows the flight path set by the approach and take-off. During this phase the body is rotated and the back is arched. The execution of the jump ends when the athlete lands on the landing mat (Jacoby & Farley, 1995). That is essentially what high jump is, a change from horizontal movement to vertical movement to lift the body above the bar.

2.2. Biomechanics of high jump

The high jump competition´s performance and improved record level depend on many kinematic variables needed to be studied.

As well as sports biomechanics is used to improve performance by developing techniques and to improvise the latest techniques to minimize injuries, maximize performance, develop exercise mode and lastly modify sports techniques. So, for the long jump, triple jump and high jump, the biomechanical principle will be able to minimize injuries and improvise performance (Ismail, 2002). However, 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. (Hong, et al, 1996) indicated that correct execution of body movement leads to successful sports performance. Only sport biomechanics that can provide valuable kinematic information of sport movements, in countries, such as United State, Australia and Germany where sports and sport science are well developed, the study of biomechanics has already been proved as a major scientific tool for innovation of techniques and thus achievement in performance. 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. Also, 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).

Also, (Simonian, 1981) added that biomechanics is essential for physical educators, coaches, and other in the business of teaching or analyzing the human motion. The high jump, as we know it today, became popular in 19th Century and was included into the program of the first modern Olympic Games in 1896. The most primitive technique for clearing the bar is the “Scissors Style”, in which a straight run-up is used. From there, the technical evolution of event has included techniques known as the “Western Roll”, the “Straddle” and the “Fosbury Flop”, which is the most fashionable at present. Dick Fosbury (USA), winner of the high jump at Olympic Games in Mexico City, is credited with being the first athlete who successfully use the back lay-out clearance from a curved approach. Almost all modern high jumpers use the flop and the current world records (men: 2.45 m, women: 2.09 m) were set with this technique (Ae, et al, 2008).

On the other hand, a high jump can be divided into three parts: the run-up (approach) phase which server as preparation for the take-off phase, the take-off phase, the most important part of the high jump, and the flight (clearance bar) phase (Dapena, 1992; Bradamante, et al, 2004; Vindušková & Jelínek, 2004; Ae, et al, 2008; Čoh & Supej, 2008).

2.2.1. Run-up phase

The purpose of the run-up is to set the appropriate conditions for beginning of the take-off (Dapena, 1992).

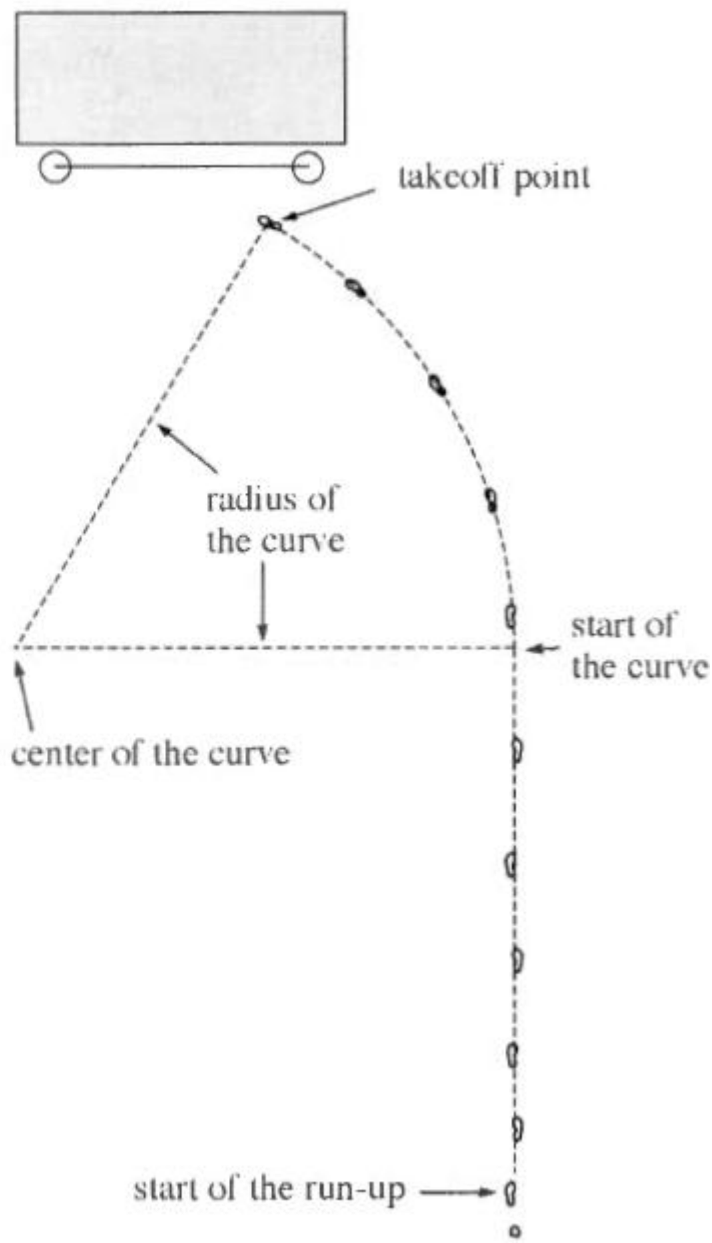


Figure 2: Last four or five steps follow a curve (Dapena, 1992)

Most jumpers who use the Fosbury Flop technique have a curved approach run. The typical length of the run up for experienced jumpers is about 10-12 strides.

The first part of the run-up usually follows a straight line perpendicular to the plane of standards, and the last four or five strides follow a curve with a radius of approximately 8 to 12 m. Inward lean of the body during the curved section 'automatically' results in a lowering of the CM in the direction of the center of the curve. The degree of inward lean is dependent on the run-up velocity and can be greater than 30°**.** The corresponding percentage lowering of the CM is approximately 13% in the case of a 30° lean, to 18% in the case of a 35° lean, if one converts the absolute values of 0.12 to .015 m. The maximum degree of lowering is reached during the penultimate stride (Alexander, 1990; Dapena, 1990, 1). One of the main purposes of the curve is to make the jumper lean away from the bar at the start of the take-off phase (Alexander, 1990; Dapena, 1992).

Figure 8 also shows angles t1, p2, p1 and p0: t1 is the angle between the bar and the line joining the last two footprints; p2 and p1 are the angles between the bar and the path of the CM. in the airborne phases of the last two steps; p0 is the angle between the bar and the path of the CM. during the flight phase that follows the take-off. The angles are smaller in athletes who move more parallel to the bar (Dapena & Ficklin, 2007).

The objective of any jump approach is to produce an accurate take off, generate maximal controllable velocity and place the body in suitable posture at take off. The requirement of speed, accuracy and posture in the successful approach and jump is oftentimes a difficult blend for elite and novice competitor alike (Lundin & Beg, 1993). Figure 3 shows the last three steps on run-up phase.

The jumper needs the horizontal velocity from the run-up to provide him with enough speed to cross the bar. For world-class male athletes the speeds are about 7 $m.s^{-1}$ because a fast run-up makes for a large horizontal component of velocity at take-off, but shortens the duration of ground contact and hence restricts the vertical impulse. However, they primarily need the horizontal velocity to produce great force on the jumping leg as it is placed ahead of the body at the plant of the take-off foot. In this position the resistance to further forward movement in the amortization (sinking phase) of jumping foot creates tremendous force (equal to 4

X body weight) which is returned partly as vertical spring if the leg is capable of resisting such force (Alexander, 1990; McWatt, 1990; Bourne, 1990). In other words, the run-up phase helps the jumper create a more vertical force, which he enhances by swinging his arms and free leg upward before he leaves the ground (Whitehead, et al, 1996).

In summarization, an error during the approach run will cause the take off, and thus the jump, to be compromised to some extent. The resultant jump is simply a modification of running mechanics, for better or worse. Considering that good execution of the run is prerequisite to proper takeoff and flight mechanics, it is logical that much time and effort be devoted to teaching this technical component, developing it into a contributing, rather than a hindering, factor (Schexnayder, 2005).

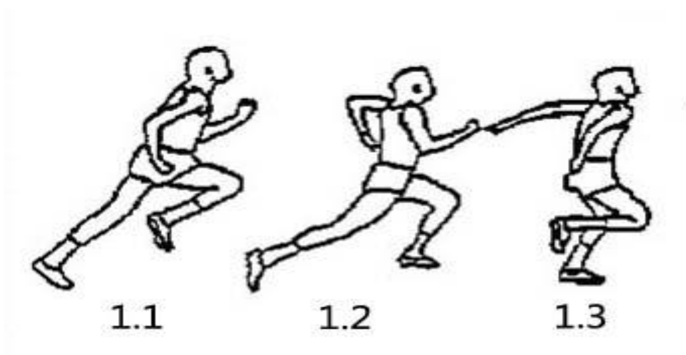


Figure 3: Last three strides in run-up (Swedan, 2007)

2.2.1.1. Arm action at run-up phase

During the take-off phase a strong upward acceleration of the arms is desirable. For this acceleration to be possible, the arms should be appropriately positioned during the last strides of the run-up. This positioning of the arms must not interfere; however, with the horizontal speed of the run-up. Up to the last two strides of the run-up, the actions of the arms should be relaxed, with a natural alternation of legs and arms. When the left foot makes its penultimate contact with the ground, most jumpers are in a similar posture, with the left leg and right arm forward, and the right leg and left arm back. From this moment, several different techniques can be observed in different jumpers:

1. Some jumpers maintain the natural alternation of legs and arms in the last two strides. Thus they reach the start of the take-off phase with the left leg and right arm forward and the right leg and left arm back (Fig. 4e, Fig. 4f).

2. From here, two variants can be observed in different jumpers:

a. "Running arm action." During the take-off phase the left arm is swung forward and the right arm is swung back, thus following the natural alternation of arms and legs through the take-off (Fig. 5). This technique was originally used by Fosbury himself. If this technique is used, it is important that the right shoulder not be allowed to drop during the take-off phase.

b. "Single arm action." During the take-off phase, the left arm is swung up as in the running arm action, but the right arm is left forward and up, practically inactive during the take-off (Fig. 5). This technique is used by many women high jumpers, although some men have also been known to use it. It is not a good technique, because the right arm does not contribute at all to the take-off effort.

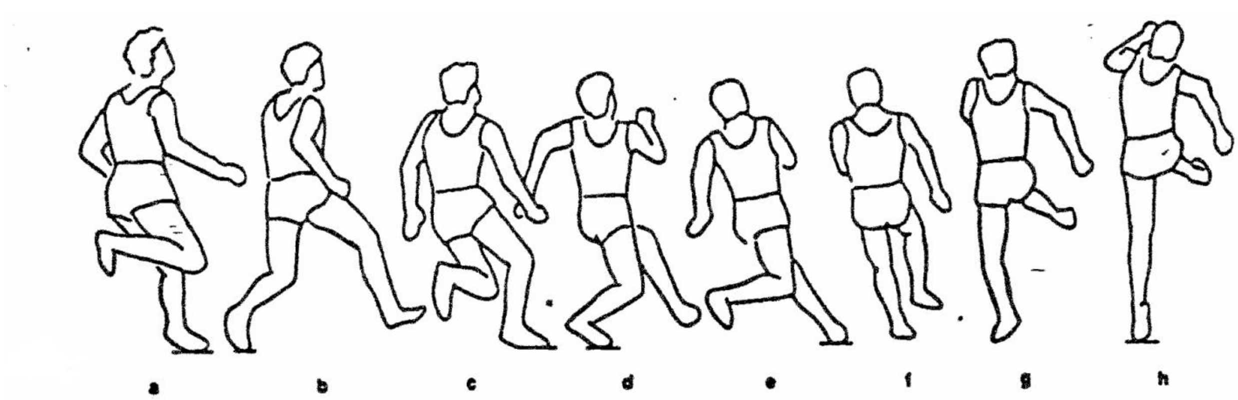


Figure 4: Arm action at run-up phase (1) (Swedan, 2007)

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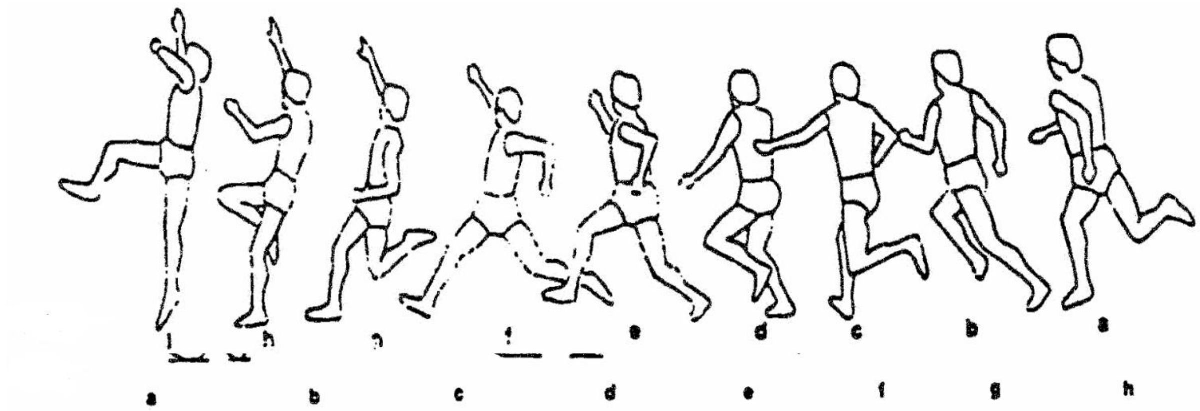


Figure 5: Arms action at run-up (2) (Swedan, 2007)

2. Other jumpers modify the natural alternation of legs and arms in the last two strides in order to reach the start of the take-off phase with the left leg forward and the right leg and both arms back. There are two basic variants of this double-arm action:

a. In the first variant, the natural alternation of arms is maintained during the penultimate stride so that when the right foot touches the ground, the left arm is forward and the right arm is back (Fig. 6a). In the last stride, the left arm moves back naturally, but the right arm is kept back (Fig. 6a-c). From this position, both arms are swung forward and ward (Fig. 6c-g).

b. In the second variant, the right arm is kept forward during the penultimate stride while the left arm moves naturally forward (Fig. 7a-b). Thus, when the right foot is about to make contact with the ground, both arms are forward (Fig. 7c). Then, during the last stride, both arms are pulled back (Fig. 7c-e). From there, they are swung forward and up (Fig. 7e-h) (Lundin & Beg, 1993; Dapena, 2011).

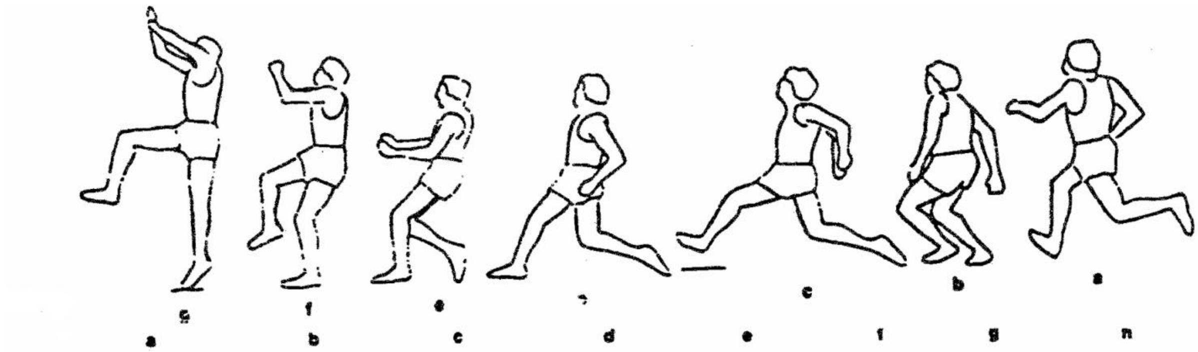


Figure 6: Arms action at run-up (3) (Swedan, 2007)

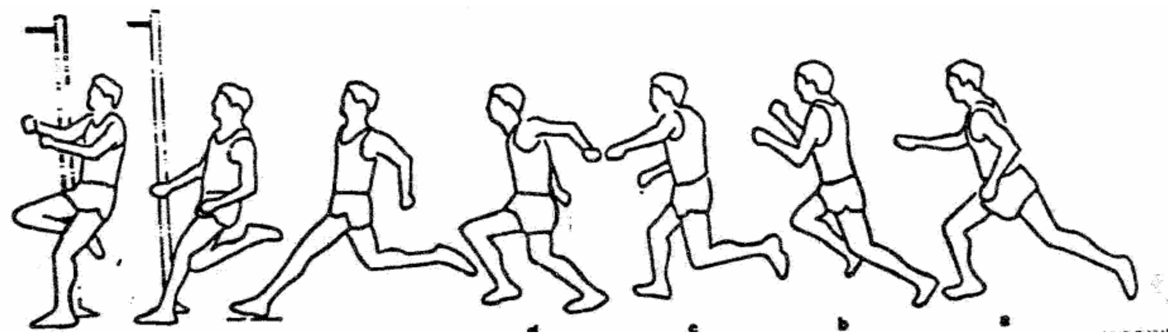


Figure 7: Arms action at run-up (4) (Swedan, 2007)

2.2.1.2. Common faults in run-up

The most frequent faults in the flop run up occur in the structure of the run-up stride, which should not differ from a natural running action. Typical errors are:

- A relaxed but not resilient foot placement.
- An initial placement of the foot on the whole sole.
- A heel-first placement of the foot.
- An insufficient forward roll on the whole sole.

These errors appear to be insignificant and are frequently overlooked. Unfortunately they can be found not only among beginners but also among high performance athletes and need attention until a natural and efficient running movement is established. Landing on a resilient foot is required to maintain high motor activity in the support phases over the entire run up. It also helps to increase stride frequency and speeds up the pre-take-off strides. The effectiveness of the flop run up is therefore directly proportional to a natural running action. It must be said that running the entire approach on a curve is classified as an error and is far from being effective. The radius of the curve must be chosen individually according to the height and weight of the jumper, as well as his coordination and speed capacities. The curved section of the run up should not exceed three to five strides (Jess, 1994).

2.2.2. The Take-off phase

One of the key parameters that directly influences jump height is the position of the CM at the end of take-off phase the maximum height of CM at the end of take-off phase largely depends on the jumper's anthropometric characteristics (body height) and take off technique (efficient extension in ankle, knee, hip joints and the trunk) (Čoh & Supej, 2008). (Dapena, 1990, 2) defines the take-off phase as the period of time between the instant when the take-off foot first touches the ground (touchdown) and instant when it loses contact with the ground. In addition, (Dapena, 2006) divides the take-off phase into the "start of the take-off phase" and the "end of take-off phase". The start of take-off phase lasts from the when the take-off foot contacts the ground until the moment of maximum flexion (amortization) in the knee of take-off leg. According to (Dapena, 2006; Čoh & Supej, 2008) the entire phase lasts from 0.14 to 0.18 of a second. The optimum angle between the foot and the bar line is 20^0 to 25^0. The distance from take-off point to the bar is very individualized and depends on the velocity of the jumper, the approach technique and the bar-crossing technique. As a rule, the distance is between 0.90 m to 1.40 m, in this phase, the intensive transformation of the horizontal velocity into vertical velocity occurs as consequence of the ground reaction force acting in backward and upward direction. (Isolehto, et al, 2007; Ae, et al, 2008; Čoh & Supej, 2008) added the partial change in the CM in the take-off action is mainly related to transform of the horizontal velocity into vertical velocity of the CM during the take-off phase, The vertical velocity at the end of take-off phase is the key generator of the jump height. To maximize vertical velocity at the end of the take-off, the horizontal velocity of the C.M at the start of the take-off phase is very important as it must be as great as possible (Dapena, 2006). According to some studies (Dapena, 2006; Isolehto, et al, 2007; Ae, et al, 2008; Čoh & Supej, 2008) the vertical velocity of elite high jumpers at the end of take-off phase is 3.8 to 5.0 $m.s^{-1}$. Also, during take-off action, the horizontal component of velocity of jumper's CM decreased by 4.45 $m.s^{-1}$ and the vertical component increased by 4.16 $m.s^{-1}$. Based on this decrease in horizontal velocity in the take-off action, it can be established that the change is extreme. With elite jumpers, the decrease in velocity equals 3.47 ± 0.28 $m.s^{-1}$.

Force comes first from the checking plant of the jumping legs influence by the speed of the run-up. It also comes from swing of free arms and leg. To gain maximum force from these actions the acceleration must be fast and early, especially for the free leg, for it is then that it adds by a downward centrifugal force to already amortizing support leg. The greater force, the greater the reaction to force, and the same time, more power (McWatt, 1990).

In high jump, as the upward swing of the free leg and the arms slow down (as long as we have contact with ground), the angular momentum is transferred to the body as whole, thus assisting the work of the extending leg, The more momentum, the greater transfer. Angular momentum is the product of angular velocity and the moment of force (mass x length of moment arm). It would seem then that the greater the length of the moment arm, the more momentum would be generated. It is only in the high jump, however, that we have sufficient time 0.14-0.18 second to develop this momentum (McWatt, 1990).

If we start from ground level with our CM then the best angle of projection for distance jumping is 45º and for height 90^0. However, the athlete's CM is always some height above ground level at take off and a high jumper must cross the bar and so must have a forward angle of some kind (McWatt, 1990).

The high jumper also makes adjustment in angle of projection. It varies according to speed of his approach and the angle of approach to the bar. Generally, however, for men take-off angles will be in the range of 45^0-55^0. Women are generally lower. In recent years, with faster approaches, the angles have been reduced (McWatt, 1990).

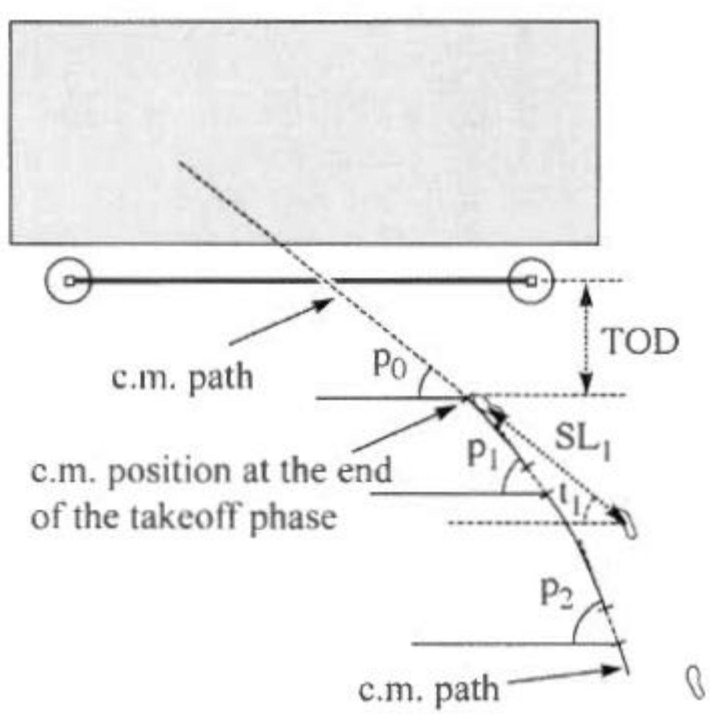


Figure 8: shows an overhead view of the last two run-up, take-off and flight phase (McWatt, 1990)

In high jump especially 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 (McWatt, 1990).

The main difference in the take-off of high jump is that body lowers more to precipitate a take-off angle of 45^0-55^0 (Myers, 1989). Figure (9) shows the take-off phase:

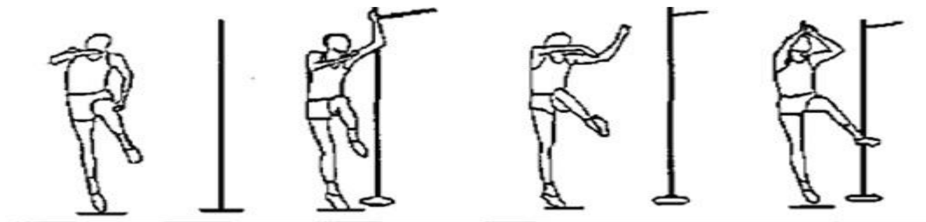


Figure 9: Take-off phase (Swedan, 2007)

2.2.2.1. Common faults in the take-off phase

The preparatory action and the movement structure of the take-off in the flop have a lot of common with the take-off in the long jump. The main difference is in the influence of centrifugal forces that make the performance of movements more difficult in the high jump. The task of achieving a strictly vertical position at the end of the take-off phase under the influence of centrifugal forces is extremely hard. As a result, jumpers often lean towards the bar before the take-off has been completed. The center of gravity is shifted sideways from the direction of the take-off, restricting a full exploitation of the action. This is a major fault that can cost 0.08 to 0.1 m for lower level and 0.03 to 0.05 m for top level jumpers.

The initial position of the jumper in the phase of planting the take-off foot is also important. The main fault that occurs here is a sideways lean of the trunk towards bar when the take-off foot is grounded. In addition, the jumper lowers the shoulders closer to the bar and begins to rotate the back in the direction of the jump. Another fault occurs when the planting of the take-off foot coincides with a vertical position of the jumper’s body over the support. In the end, we should focus our attention on the position of the trunk and shoulders in the final take off phase which is responsible for 80 to 90% of all the faults that occur. It is common to find that the jumper’s back it turned towards the bar with right shoulder moving forward and the left backward. The result is that the jumper’s center of gravity is shifted from the vertical position. This can be corrected in training by employing straight run up from different angles and alternating there with jumps from a curved approach (Jarver, 1994).

2.2.3. The Flight phase

The bar clearance technique is less important in high jump event: most bar clearance technique problems actually originate in the run-up or in the take-off phase (Dapena, 1990, 2). Also (Strishak, 1988) confirmed that faults that occur in the bar clearance are usually created in the preparation and execution phases of the take-off.

After the take-off is completed, the parabolic path of the CM is totally determined, and there is nothing that athlete can do to change it. However, this does not mean that the paths of all parts of body are determined. What cannot be changed is the path of the point that represents the average position of all the body parts CM, but is possible to move one part of the body in one direction by moving other parts in the opposite direction (Dapena, 1996; Tidow, 1990). Moreover, at the instant that take off foot loses contact with the ground; the CM of a high jumper is usually at a height somewhere between 70% and 75% of standing height of the athlete. This means that tall high jumpers have built- in advantage: their CM’s will generally be higher at the instant that they leave the ground (Dapena, 1992).

High jumpers also try to clear the bar with their CM as low as possible. Many high jumpers roll their bodies horizontally over the bar in an attempt to get their CM as low as possible. In doing this, the jumpers’ move their CM outside their bodies, and their CM may pass under the bar while their bodies go over the bar (Whitehead, et al, 1996).

Once in the air, the high jumper makes a twisting somersault rotation which leads to a supine layout position over the bar. Problems in twist rotation can produce a tilted position, with one hip lower than the other; the lower hip limits the result of the jump. An under twisted position with the hip of the lead leg lower than the hip of the take-off leg at the peak of the jump is the most common problem (Dapena, 1990, 2), but there are other factors that can also have some effect on the rotation. By speeding up the rotation of some parts of the body, other parts of the body will slow down as compensation, and vice versa. Another way in which rotation can be changed is by altering the (moment of inertia) of the body. When many parts of the body are far from the CM, we say that the “moment of inertia “of the body is large, and this decreases the speed of rotation. Vice versa, if all parts of the body are kept close to the CM, the moment of inertia of the body is small, and the speed of rotation is increased. This is similar to what happens to figure skaters when they spin: As they get their arms closer to the body, they spin faster (Dapena, 1990, 1; Tidow, 1990).

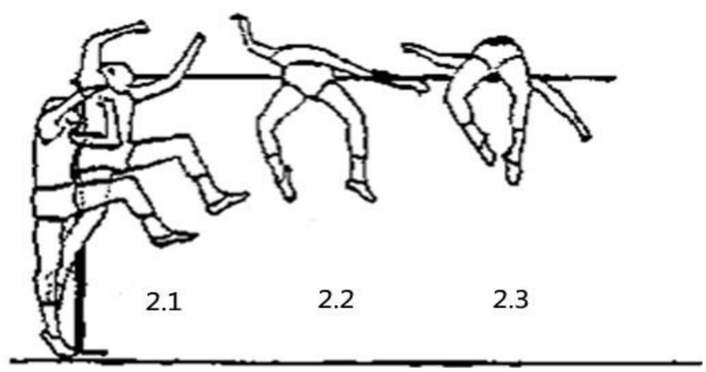


Figure 10: The flight phase (Swedan, 2007)

2.2.3.1. Common faults in the flight phase

Faults that occur in the bar clearance are usually created in the preparation and execution phase of the take-off. This must be kept in mind to avoid paying extra attention to the clearance phase which unfortunately happens far too frequently. There are only a few major faults common to bar clearance. The first takes place when the jumper dislodges the bar because of the lack of visual control. This can be avoided by taking into consideration that the head position directs the flight. The second common fault is passive transition of the jumper over the bar. Active movements of the pelvic girdle help to speed up the rotational action over the bar. Also, increasing the arch in the waist area makes it possible to increase the upward lift of center of gravity and to reduce the time over the bar, thus decreasing the possibility of dislodging the bar. Finally, a common error that occurs shortly after the completion of the take-off, it takes place when the lead leg is allowed to remain in its take-off position. Holding both legs in place after the take-off restricts the following rotation around the bar and should be avoided by lowering the lead leg towards the take-off leg after the jumper had left the ground. A similar error happens when both arms are directed above the bar after the take-off and are not directed towards the hips to be kept alongside the trunk (Jarver, 1994).

2.3. Three dimensional analyses at high jump event

Human movement analysis is not a new science. In fact, Giovanni Borelli is credited as being the first to make dynamic calculations of human movement during the Renaissance. Analysis using sequences of photographs has been done since 1870 where Muybridge analyzed human and animal movements. That continued until cinematographic picture technology came about, which then became the primary technology used for movement analysis. What analysts would do is measure the distance an object moved from one frame to the next and from that, they were able to make calculations such as velocities and accelerations (Galloway, 2006).

Up until the last 25 years or so, Human movement analysis using video recordings were limited to movements carried out in just one plane, which involved a two dimensional analysis. It became increasingly apparent that most complex human movements involve motion in more than one plane, leading to the development of three-dimensional video analysis techniques (Pearson, 1996).

Over the last years, several methods of enhancement in sports television were introduced, e.g. a moving line enabling the comparison of an athlete’s attempt with the world record, or the overlay of two competitors for comparison of their skiing technique etc. Due to the nature of traditional television, these enhancements were previously limited to 2D sequences the TV viewer cannot interact with.

Also, (Galloway, 2006) confirmed it was not until the past 25 years that electronic and computer technology progressed to the point where it could be utilized for tracking and analyzing human movement. With improving technology, the range of influence that 3D human movement data capturing and analysis has on other fields of science and research continues to broaden .The use of cameras and image based analysis is growing in society today. Image analysis methods have been a very active area of research for a long time. Applications of the image based methods have historically been rare even though the theory has been solid (Holmberg, 2005).

High speed video analysis has been the most widely used method of study to date, and given precise data collection and analysis, appears to be a reliable and valid method for kinematic and kinetic analyses (Pearson, 1996).

We can mention above that motion analysis is very important for sports performance enhancement and injury prevention (Gopalai & Senanayake, 2008).

However, Iiker Ycesir, a professor at the School of Physical Education and Sports at Istanbul University, defines modern human movement analysis as “the interpretation of computerized data that documents an individual’s upper and lower extremities, pelvis, and trunk motion during movement (Galloway, 2006).

Sports science and athletes can greatly benefit from advances in 3D human movement analysis technology. Aspiring amateurs and professionals alike can learn the proper mechanics faster cognitively and through muscle memory. Also, ensuring that physical activity is performed with proper mechanics can help prevent future injuries like tendonitis (Galloway, 2006).

2.3.1. Three dimensional 3D motion analysis

In three dimensions, we would need three numbers to describe the position of an object in space. To describe the position of something in space, we need to identify a fixed reference point to serve as the origin of our coordinate system. For our purpose, any point fixed relative to the earth will do. Then we set up a Cartesian coordinate system. If we only describe the position of object in one dimension, only one axis is need, for two axes are needed, and for three dimensions, three axes are needed. The axes of this system may point in any direction that is convenient, as long as they are at right angles to each other if we are describing the position of something in two or three dimensions. Typically, one axis will be oriented vertically (the y-axis), and the other axis (the x-axis) or axes (the x- and the z-axes) will be oriented horizontally. Each of these axes will have a positive and negative direction a long them. The x-coordinate of an object is the distance the object is away from the plane formed by y- and z-axes. The y-coordinate of an object is the distance the object is away from the plane formed by the x- and z-axes and the z-coordinate of an object is the distance the object is away from the plane formed by the x- and y-axes. Unites of length are used to describe position (McGinnis, 2005).

To produce video – based three dimensional 3D motion captures, a number of cameras need to be used so that “depth” data can be obtained as well as the planar information obtainable from a single camera. One good technique for doing this the direct linear transform (DLT) method using two or more video cameras. This technique relies mathematical transformation between raw 2D camera data (u, v) and the actual 3D coordinates (X, Y, Z) of a point. The basis of transformation is the idea that the views from each camera are governed by the laws of perspective so that apparent distances and orientations in the image are determined by the position and orientation of the camera and the transform itself is characterized by 11 constants (i.e camera parameters). An example of the perspective from the points of view of two cameras (Griffiths, 2006).

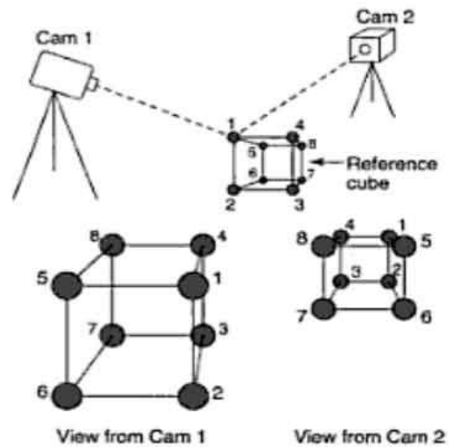


Figure 11: Views from two separate cameras of cube with markers at each comer (Griffiths, 2006)

The DLT equations are

{U = (aX + bY + cZ + d)/(iX + jY + kZ + 1)}

And {v = (eX + fY + gZ + h)/(iX + jY + kZ + 1)}.

If you have six or more calibration points with know (X, Y, Z) and corresponding raw camera coordinates (u, v) the camera parameters a, b, c ………….., k can be calculated because you have 12 or more equation (two for each calibration landmark) with 11 unknown, This done for each camera. When the camera parameters are known, the unknown (X, Y, Z) coordinates of other landmarks can be obtained from the (u, v) data of two or more cameras because there are four or more equations for the unknowns (X, Y, Z) (Griffiths, 2006).

2.3.2. Coordinate systems

Two coordinate systems must be defined when conducting a 3D analysis. There are the global or laboratory coordinate system (GCS) and the local coordinate system (LCS).

Global coordinate system

The GCS is also referred to as the inertial reference system, and it determined when the object space is defined during the 3D data capture. This coordinate system – generally a right – handed, orthogonal system with an arbitrary origin – defines the fixed coordinate system in the laboratory from which all positions are ultimately derived. The GCS is designated using uppercase letters with the arbitrary designation of X, Y and Z. In addition, the X- axis is pointed nominally in the mediolareral direction, the Y – axis anteroposteriorlly, and the Z – axis vertically. The unit vectors for the GCS are I, j, and k respectively.

2.3.3. Local coordinate system

The LGS is a reference system that is fixed within a body or segment. Like the GCS, the LCS is also a right – handed, orthogonal coordinate system with the origin generally placed at the center of mass of body or segment. The LCS is designated in lowercase letters x, y and z the until vectors are I, j and k respectively, the LCS is oriented such that the x axis of the LCS points the mediolareral direction, the Y – axis anteroposteriorlly, and the Z – axis axially. The orientation of the LCS to the GCS defines the orientation of the body or segment in space, and it changes as the body or segment moves through the 3D space.

How the LCS is defined, however, depends on how the markers to be digitized or tracked are placed on the body or segment in question. The GCS and their respective unit vectors are depicted.

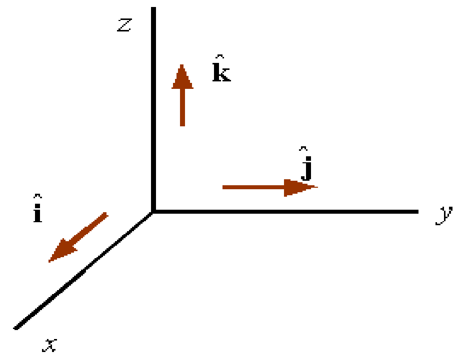


Figure 12: Global or fixed coordinate system (Gordon, 2004)

2.3.4. Marker systems

Many of the same assumptions that we used for 2D analysis apply to 3D. The most important of these is that the body consists of rigid segments. Segments are considered rigid if the length of the segment does not change. This of course, is not true; the skeletal structures we are dealing with are not rigid structures. However, by making this assumption we avoid "messy" mathematical situations for which we cannot find a solution. We must use a set of at least three no collinear points on each segment to define a rigid body in 3D space. No collinear means that the points are not a straight line (Gordon, 2004).

The other author (Holmberg, 2005) added the human anatomy is a complex system that does not easily lend itself to making direct measurements of the quantities of interest. Such quantities are for example joint positions and joint angles. (Gordon, 2004) mentioned that it should also be understood that when we measure the kinematics of a body or segment, we are attempting to determine the actions of the skeletal structure.

2.4. Research studies

2.4.1 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 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. The most important factor related to the vertical velocity of TO is the low CM position at TD ($r=-0.70$, $p<0.01$).

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. 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.

2.4.2. 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 (H3 value) 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 PB 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. 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. 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.

2.4.3. 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 cleared 2.35 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 shot 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 º. 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.

2.4.4. 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 I 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 view 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.

2.5. Conclusion of literature review

As a result of the literature review and relative studies that have been done on the high jump event, the researcher has found most of them place an emphasis on the take-off phase which is most important phase to get the best performance in the high jump event. This literature has helped the researcher to choose and identify the most kinematic parameters and what should be measured.

According to some studies conducted by various authors, the take-off phase is important phase in high jump event (Čoh & Supej, 2008; Ae, et al, 2008). This is because the vertical velocity and the height CM at the end of the take off phase, both of them determine the height CM at the moment of the bar clearance (Dapena, 1990,2; Isolehto, et al, 2007) affirmed that the peak height CM is totally determined at the end of take-off phase. It is determined by the height CM at the end of the take-off phase and by its vertical velocity at the end of the take-off phase. Also, the literature review confirm on the importance of some kinematic parameters which will study in this research, including: the velocity at the end of the run up phase, the vertical velocity at the end of the take-off phase, the height CM at the start of the take-off phase, the height CM at the end of the take-off phase, the peak height CM at the flight phase, take off time, and some angles on the some parts of the body (Dapena 1990, 1; Isolehto et al, 2007; Čoh & Supej, 2008; Ae, et al, 2008; Vindušková, et al, 2008).

Finally, the literature reviews have also helped the researcher to select the kinematic parameters which should be analyzed in his research as well as which will be considered and discussed as well as the selection of equipment.

3. Methodology

3.1. The problem of study

The problem of research has risen because of the declining of the jump record level in Egypt is (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 levels 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 researcher was unable to find even one study of the high jump in his faculty in Prague, which has studied the jumpers in North Africa. Also, he could not find even one three dimensional analysis movement of the high jump event in his country.

3.2. The aim

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

3.3. Scientific question of study

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

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

3.4. Hypothesis

1. The researcher supposes that the Egyptian athletes will have different kinematic parameters in comparison with the World elite.
2. The researcher assumes that the values of kinematic parameters for athlete (A_1) will be different with athlete (A_3).

3.5. Method

In the case study, the researcher strives for an in depth understanding of a single situation or phenomenon. This technique is used in many fields as physical education and sport. The case study is a form of description and gathers large information about one or few athletes or participants. Consequently, through in depth study of a single case, a greater understanding about similar cases is achieved. This is not to say, however, that the purpose of case studies is to make generalizations. On the contrary, drawing inferences about a population from a case study is not justifiable. In most studies, random sampling is not used because the purpose of a research is not to estimate some population value but to select cases from which one can learn the most. On the other side, the researcher has selected his sample by deliberate manner which focus on a limited number of respondents who you had selected because you think their in-depth information will give good insight into an issue that little is known about. In many ways, case study research is similar to other forms of research. It involves the identification of the problem, the collection of data, the analysis and reporting of results. As in other research techniques, the approach and analysis depend on the nature of the research problem. Case studies can be descriptive, interpretive, or evaluative. The researcher has applied the descriptive and interpretive method (evaluative case study) because of its suitability to the aim of study and posed study question. Given that the study was focused on just three athletes, generalization of analysis results can only be limited. However, this was a very specific experiment where the results clearly have an important theoretical and practical value for biomechanical study of high jump technique modeling. The case study is used in qualitative research to deal with critical problems of practice and to extend the knowledge base of various aspects of education, physical education, exercise science, and sport science (Thomas & Nelson, 2001).

3.6. 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.

The researcher used other three high jumpers to compare their results with his high jumper's results. Finalist in the high jump at 2005 IAAF World Championships in Athletics was a very high level competition in which all of the top three jumpers cleared (2.35 m) (table, 4). The stadium audience, the media and athletics fans around the World were particularly fascinated by contrast in styles exhibited. Most of the finalists had what could be termed orthodox styles of flop technique. In particular, the third placer Yaaroslav Rybakov (RUS) (A_6) showed a beautiful style, which included a double arm swing from a deep backward lean of the body at touchdown of the take-off foot. On other hand, the style of inexperienced young winner Yuriy Krymarenko (UKR) (A_4) would be best described as unusual looking, as he ran up and jumped like making a shot in basketball and then cycled his legs before clearing the bar in airborne phase.

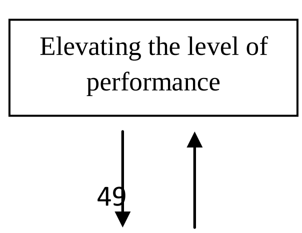
This study gives interim results of the kinematic analysis of the high jump in at 2005 IAAF World Championships, focusing on the jumping techniques of top three placed jumpers in men's event (Ae, et al, 2007).

3.7. Design of study

The use of three dimensional analyses of kinematic methods, computer technology, expert knowledge and associated artificial intelligence enable us a completely new approach to study of the athlete’s performance on basis of expert modeling. The high jump is typical technical track and field discipline where the achievement is to a large extent depending on the level of mastery of specific movement patterns. Specific movement patterns determined by biomechanical, motor, morphological and neuropsychological factors define the technical model of the high jump. Objective studying of the segment of the athlete’s preparation was made possible by the introduction of modern the dimensional video-kinematic analysis (Čoh.M, et al, 2002; Čoh.M & Supej. M ,2008).

(Tenenbaum & Driscoll, 2005) said that it is of importance to conduct a study which is identical to the intended study but with a limited number of participants. This procedure is aimed at refining the tools and devices needed for the study and making final alterations in the study procedure (protocols) prior to collecting data for the study.

This study was divided into two parts which are the pilot study and basic study.



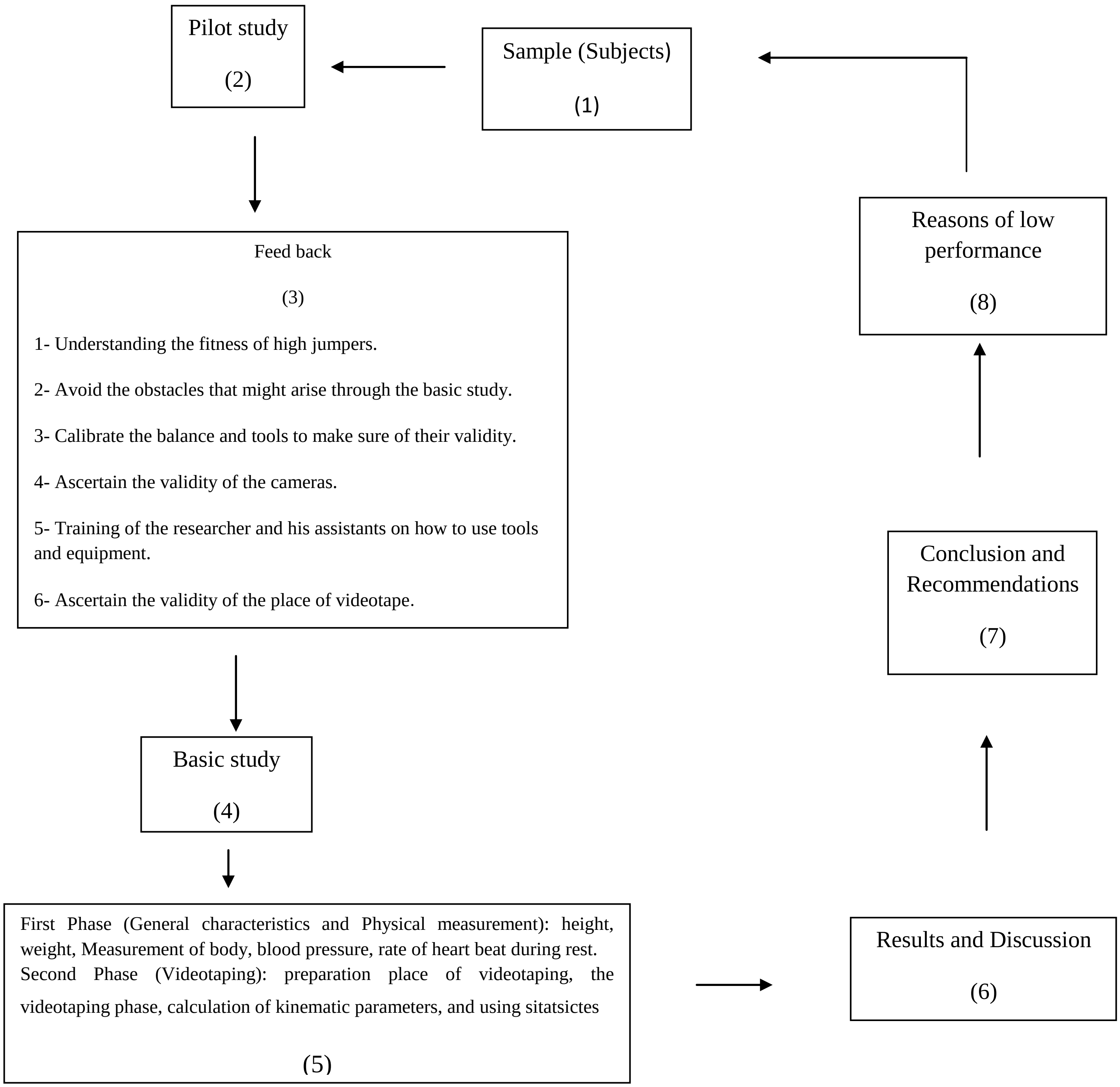


Figure 13: Simplified of the research methods (technique)

3.7.1. Pilot study

It was focused on the sample of study. The pilot study was done with the help of assistants, 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.

3.7.2. 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 a similar 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, measurement of body, weight, height, 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 14). 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 14). 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.

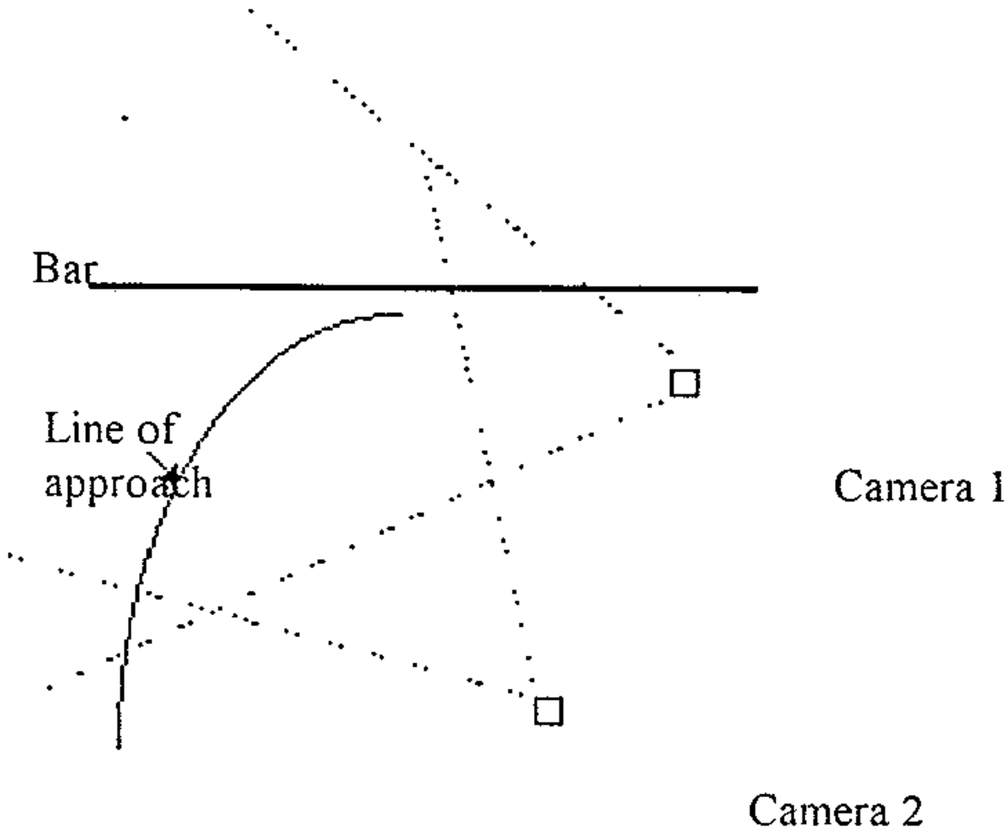


Figure 14: Arrangement and placement of two cameras

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.

$$V = d/t \quad \text{where is d = distant and t = time.}$$

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:

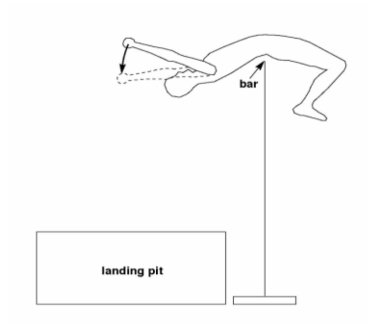


Figure 15: Peak height CM at flight phase (Swedan, 2007)

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

$$V_0 = 2h\backslash t \quad \text{where is t = time of take-off phase}$$

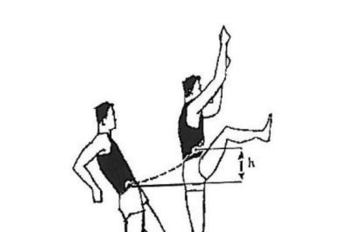


Figure 16: The difference between the height CM at starting and ending take-off phase (Swedan, 2007)

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

We will talk about the velocities of CM in the results and discussion.

After all, 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.

3.8. Conclusion of methodology

The style of methodology in this study, allows a lot of detail to be collected that would not normally be easily obtained by other research designs. The data collected form the sample and motion analysis are normally a lot richer and of greater depth than can be found through other experimental designs. One advantage of this method is that it provides a great amount of description and detail on our athletes. Researcher, coaches and athletes could learn a lot from this sample. He has taken this sample because we should know how the elite of high jumpers were in this stage before reaching high level of performance. This volume of details suggests many future research questions to follow up in other studies and help us to improve our athletes to get the best performance level in future. On other hand, the chief disadvantage of the motion analysis and case study is that the results might not generalize to others. In other words, the experiences of our sample (Egyptian high jumpers) might not apply to other high jumpers especially elite jumpers. The Researcher, he was doing this case study with the three jumpers (who were from Egypt). He has a great amount of information on these jumpers, but what he found might not be true of all jumpers. With this study, we learn and get a lot of results about one case Egyptian High jumpers, but what we learn might not apply to the larger other high jumpers. Overall, I think that this study is an important and useful method of data collection, especially in high level of high jumpers who are like our athletes. It would be extremely very expensive and difficult just to make a larger sample size to use a different experimental design method. However, as data is collected on new cases I think it is important to always refer back to previous data in order to build on existing knowledge and ensure findings are as applicable to Egyptian high jumpers as possible. In this study, the researcher has tried to use a scientific method that is not widely used in his country because he thinks that the motion analysis movement and study of physical characteristics, they will help Egyptian Athletics Unions to develop their Methods about training and selection our athletes in our countries and begin our countries with developed countries. (Hong, et al, 1996) indicated that correct execution of body movement leads to successful sports performance. Only sport biomechanics and motion analysis movement that can provide valuable kinematic information of sport movements, in countries, such as United State, Australia and Germany where sports and sport science are well developed, the study of biomechanics and motion analysis have already been proved as a major scientific tool for innovation of techniques and thus achievement in performance.

The researcher believes that the effects of physical characteristics and motion analysis of movement on the Egyptian high jumpers, they will help him to find the reasons of their weaknesses in high jump event. (Galloway, 2006) confirmed sports science and athletes can greatly benefit from advances in 3D human movement analysis technology. Aspiring amateurs and professionals alike can learn the proper mechanics faster cognitively and through muscle memory. Also, ensuring that physical activity is performed with proper mechanics can help prevent future injuries like tendonitis.

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.

4.1. Results of the Pilot study

A pilot, or feasibility study, is a small experiment designed to test logistics and gather information prior to a larger study, in order to improve the latter's quality and efficiency. A pilot study can reveal deficiencies in the design of a proposed experiment or procedure and these can then be addressed before time and resources are expended on large scale studies, but are part of a program of research. A good research strategy requires careful planning and a pilot study will often be a part of this strategy. A pilot study is normally small in comparison with the main experiment and therefore can provide only limited information on the sources and magnitude of variation of response measures. It is unlikely, for example, that a pilot study alone can provide adequate data on variability for a power analysis to estimate the improving of level record to include in a well-designed experiment. A systematic review of the literature or even a single publication is a more appropriate source of information on variability. The pilot study may, however, provide vital information on the severity of proposed procedures or treatments. We can attribute error in this experiment to possible incorrect analysis of the CM, since we based most of our calculations on it. This is due to the difficulty in clicking the same point on the body for each of the body parts for every frame. This automatically causes some discrepancy in the results. Also, the motion of the camera and its angle in relation to the bar cause error.

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.

4.2. Results and discussion of the Basic study

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 (Iiboshi et al, 1991; Bruggemann & Arampatzis, 1997; Dapena, 2000; Čoh.M & Supej. M, 2008; Isolehto, et al, 2007).

4.2.1. The physical characteristics 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

Table (2): The physical characteristics of the Egyptian high jumpers

Height Weight

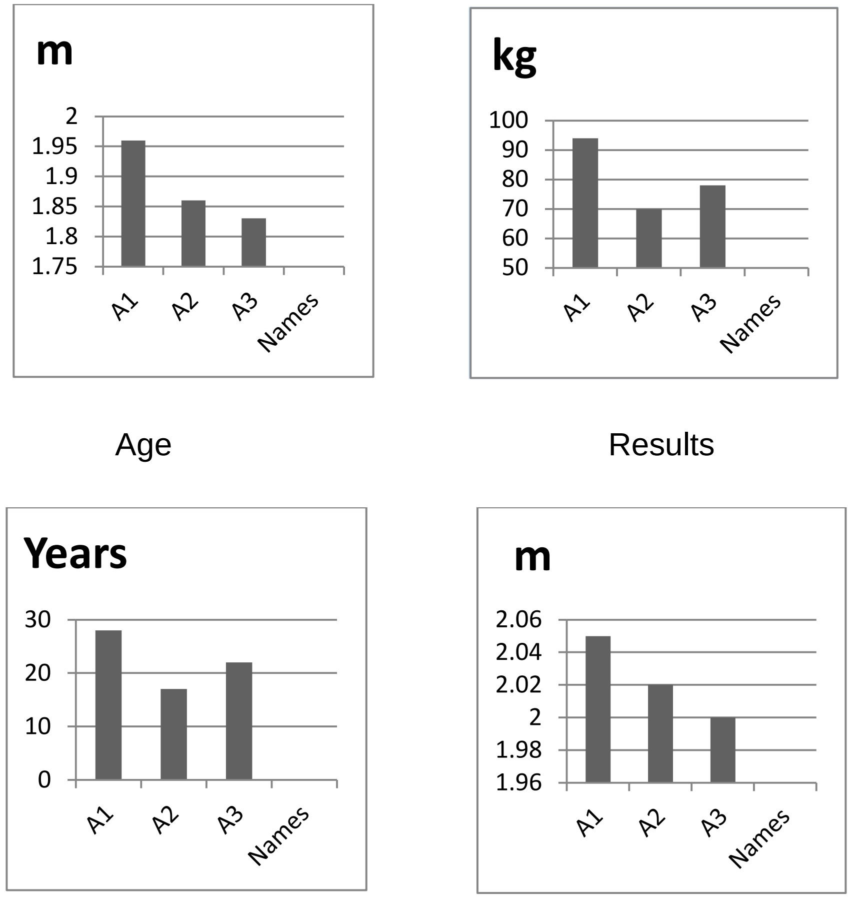


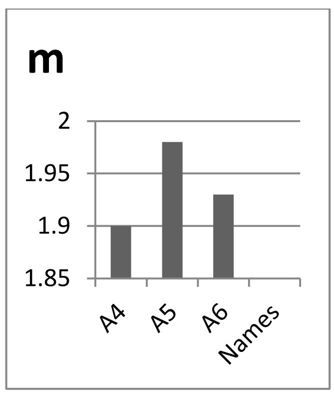
Figure 17: Chart of the physical characteristics of the Egyptian high jumpers

From figure 17 and table (2) 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 (2). 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 2,3,4,5), we can establish that the jumpers are representative of the power-Flop model of high jump technique. Their morphological 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 2,3,4.5). Table (3) show three male high jumpers at 2005 IAAF World Championship (height: 1.90, 1.98, 1.93 m; weight 75, 82, 60 kg). The high jump is complex technical track and field discipline of a cyclic-acyclic character where the result depends on numerous factors, the degree of mastering the standard movement patterns, and the morphological characteristics of high jumpers. It is precisely the latter that are from the aspect of biomechanical principles of the high jump of paramount importance. The high jump requires, in view of the dynamic and kinematic characteristics of movement, a strongly profiled structure of morphological dimensions in the high jump. Dominant are above all the physical measurements, especially the body height and leg length which directly defines the central point of the jumper's center of mass CM. 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 the morphological dimensions 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. Morphological characteristics 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 choice of potential subjects. In order to establish what is the optimal model of the morphological characteristics in high jumper. We 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.

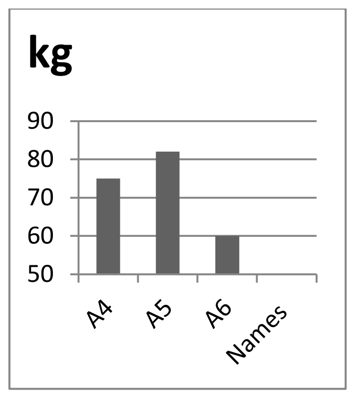
Name of athlete	Team	Height m	Weight kg	The Results m
Athlete (A_4)	UKR	1.90	75	2.32
Athlete (A_5)	CUB	1.98	82	2.32
Athlete (A_6)	RUS	1.93	60	2.32

Table (3): The physical characteristics of finalist in the high jump at 2005 IAAF World Championships in Athletics

Height



Weight



Results

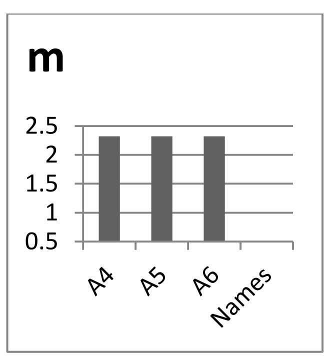


Figure 18: Chart of the physical characteristics of the high jumpers at 2005 IAAF World Championships in Athletics

In comparison the results of the study (height 1.96, 1.85, 1.83; weight 94, 70, 78 kg) by three male high jumpers at 2005 IAAF World Championship (height: 1.90, 1.98, 1.93 m; weight 75, 82, 60 kg) we can see that the parameters are in the both very similar (Table 2, 3). The body height and the body mass as the general morphological 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 the said we may conclude that top results are achieved by high jumper of various morphological 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 morphological parameters and have thus establish the model characteristics of the morphological 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. 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.

4.2.2. 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, 1981).

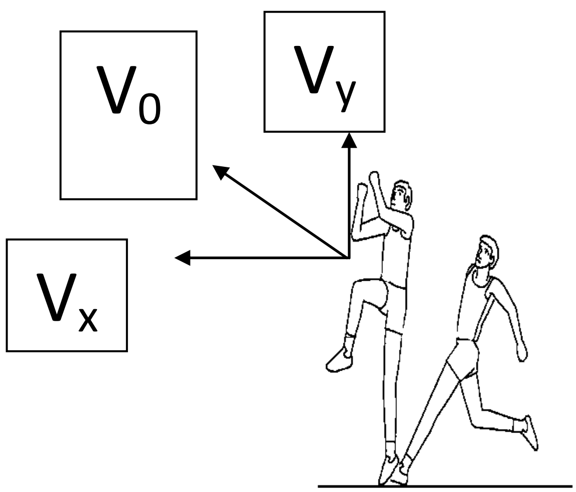


Figure 19: Horizontal and vertical velocity components during take-off (Swedan, 2007)

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 (4): 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).

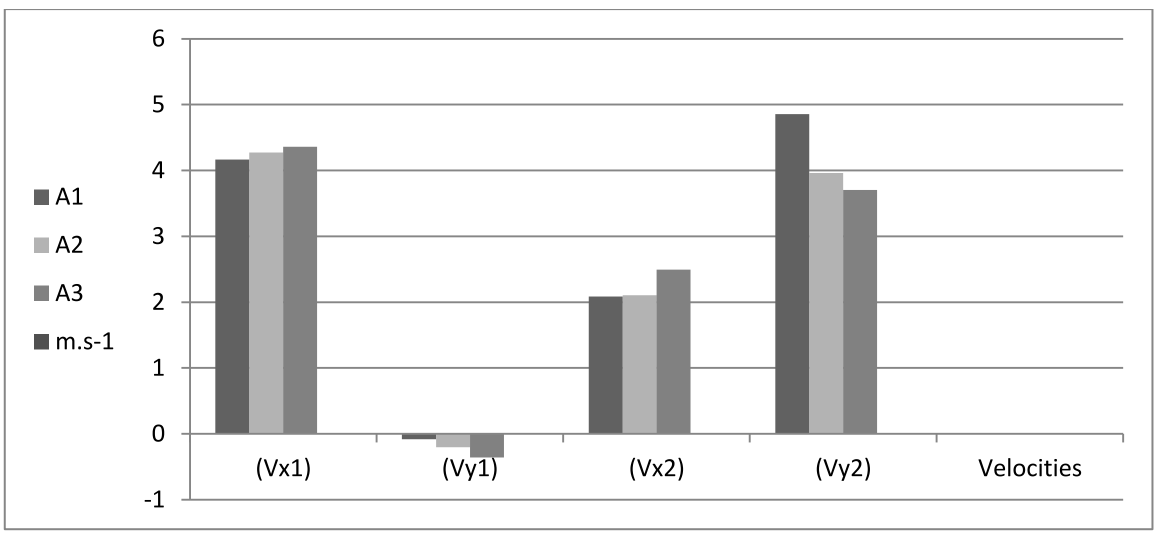


Figure 20: Chart of CM velocities of take-off action of the Egyptian high jumpers

Horizontal and vertical velocity components, Figure 19 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 45 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 2005 World Championship (7.99 $m.s^{-1}$, 7.36, 7.59 $m.s^{-1}$). In addition, Egyptian high jumpers are likely that they accelerated their horizontal velocity of CM at start take off (V_{x1}) as:

Velocities / Athletes	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

And the jumpers in the 2005 World Championship as:

Velocities / Athletes	From $m.s^{-1}$	To $m.s^{-1}$
Athlete (A_4)	7.99	4.35
Athlete (A_5)	7.36	3.75
Athlete (A_6)	7.59	4.31

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).

Horizontal and vertical velocity components figure 21, 22, 23 show the typical curves of the velocity components during the last stride, take off and fight of the three Egyptian high jumpers.

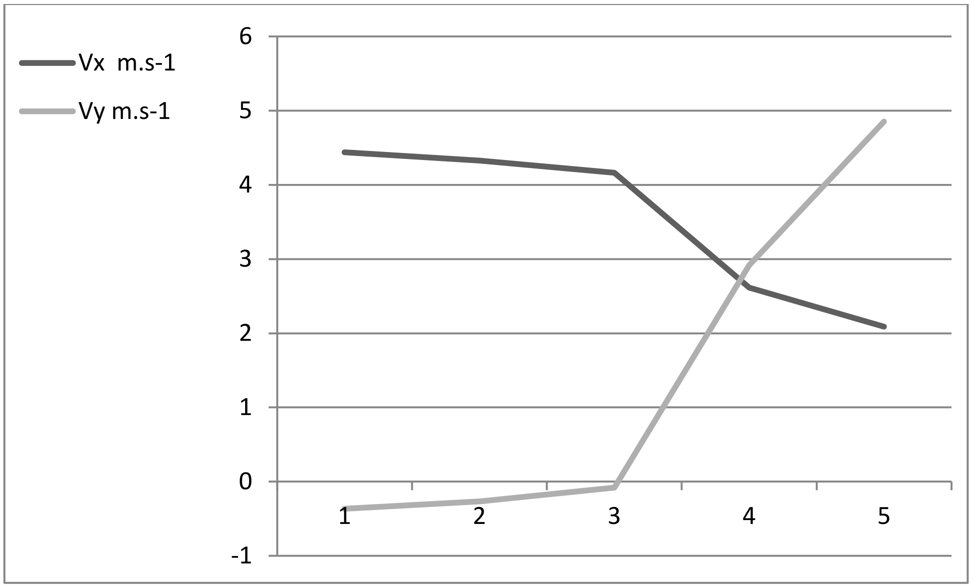


Figure 21: The horizontal and vertical velocity curves of the athlete A_1 of Egyptian high jumper

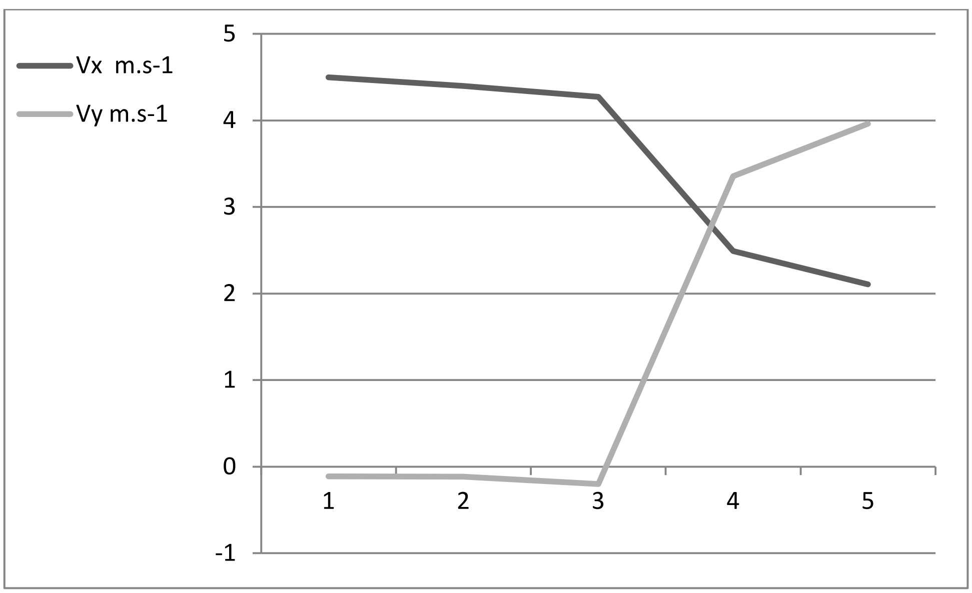


Figure 22: The horizontal and vertical velocity curves of the athlete A_2 of Egyptian high jumper

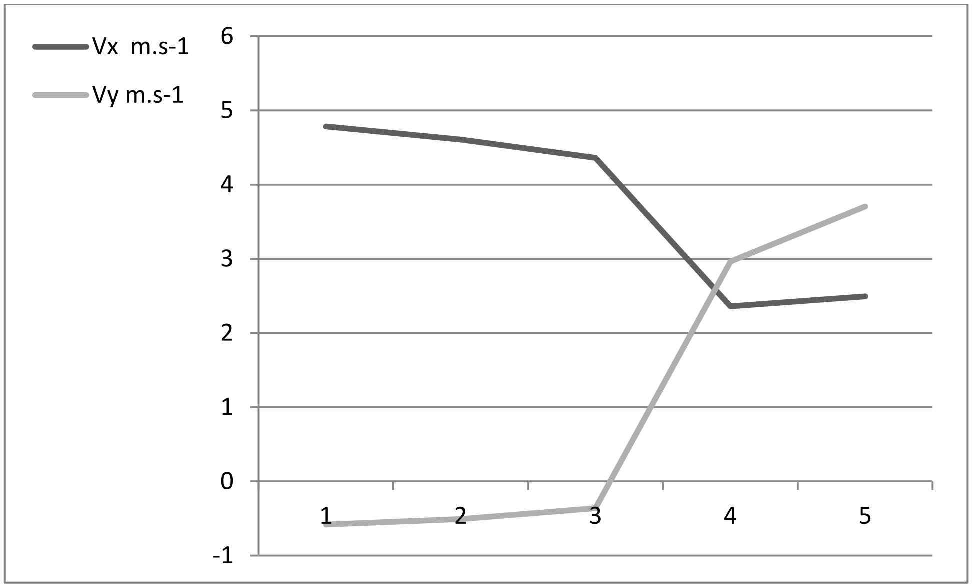


Figure 23: The horizontal and vertical velocity curves of the athlete A_3 of Egyptian high jumper

Jumpers / Kinematic parameters	Unit	Athlete (A_4)	Athlete (A_5)	Athlete (A_6)
Horizontal velocity of CM at start take-off (V_{x1})	$m.s^{-1}$	7.99	7.36	7.59
Vertical velocity of CM at start take-off (V_{y1})	$m.s^{-1}$	-0.45	-0.34	-0.45
Horizontal velocity of CM at end take-off (V_{x2})	$m.s^{-1}$	4.35	3.75	4.31
Vertical velocity of CM at end take-off (V_{y2})	$m.s^{-1}$	4.61	4.39	4.18

Table (5): CM velocities of take-off action in the high jump at 2005 IAAF World Championships in Athletics

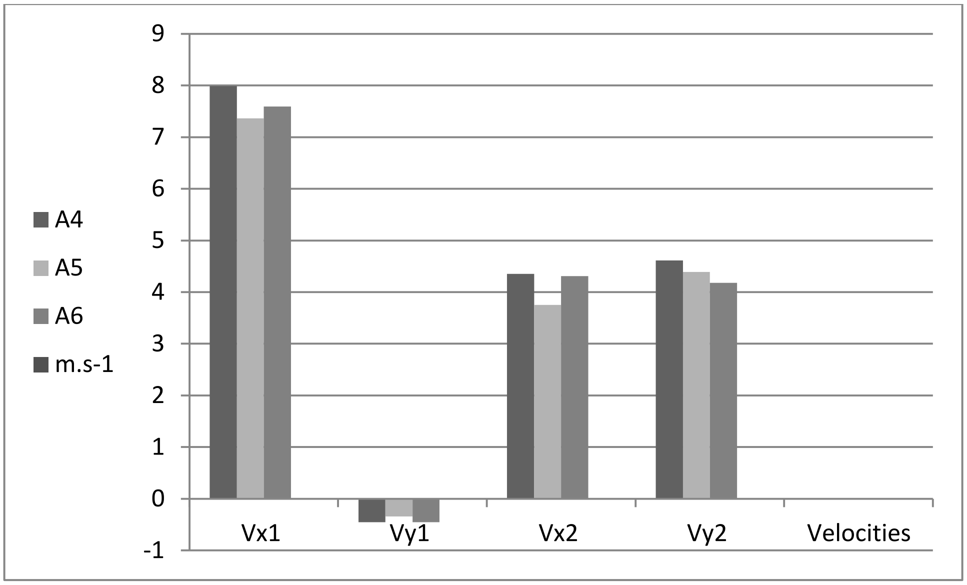


Figure 24: Chart of CM velocities of take-off action in the high jumpers at 2005 IAAF World Championships in Athletics

On other hand, the downward vertical velocity at start take off (V_{y1}) for the Egyptian high jumpers (-0.08 $m.s^{-1}$, -0.21 $m.s^{-1}$,-0.214 $m.s^{-1}$) is less than the high jumpers in the 2005 World Championship (-0.45 $m.s^{-1}$, -0.34 $m.s^{-1}$, 0.45 $m.s^{-1}$).

The vertical CM velocity was increasing from the start take off phase. It is often called a paradox that vertical CM velocity increases due to the rotation of the body around the take-off foot in spite of the fact that take off knee flexes. The Egyptian high jumpers their vertical CM velocity at the start take off phase was negative, during the take-off phase, a high jumper has to generate impulse to absorb the forward and downward vertical the CM and acquire the upward CM velocity needed to raise his body in the air. However, the vertical CM velocity at start of the take-off of athlete (A_6) was positive, although some jumpers very often transited to take-off with positive vertical CM velocity. The positive or slightly negative vertical CM velocity at start take-off phase for take-off implies that impulse to absorb downward CM vertical was not necessary or smaller than the case of large negative vertical CM velocity (Ae, et al, 2008).

It is obvious that the jumper's CM must be projected high enough at take-off to get the jumper over the crossbar, and that the peak of parabolic curve be directly over the bar. No matter how efficient the jumper's bar clearance style might be, it is worthless if the take-off has not been good. The jumper's primary concern, then, must be to improve vertical velocity at take-off, which will in turn increase the height of parabolic curve. And the only way to increase vertical velocity is to increase the vertical ground reaction forces (Ecker, 1996).

Different authors (Conrad & Ritzdorf, 1990; Dapean, 1992, 2006; Hay, 1993; Aramapatzis & Bruggemann, 1999; Isolehto et al, 2007; Ae, et al, 2008) confirm the vertical velocity at the end of take-off phase is the key generator of the high jump height. To maximize vertical velocity at the end of the take-off, the horizontal velocity of the CM at the start of the take-off phase is very important as it must be as great as possible (Dapena, 2006). During the take-off action, the horizontal component of velocity of the jumper's CM decreased and the vertical component of velocity increased. Based on this decrease in horizontal velocity in the take-off action, it can be established that the change is extreme.

Furthermore, the important factor at the end of the take-off phase is the vertical velocity of the jumper's CM. Maximum vertical velocity is consequence of the vertical ground reaction force that jumper develops at the time of take-off foot contacts the ground. The vertical velocity of elite high jumpers at the end of the take-off phase is (3.8 to 5.0 $m.s^{-1}$), which is identical to our athletes (4.85 $m.s^{-1}$, 3.96 $m.s^{-1}$, 3.71 $m.s^{-1}$) and also is identical to the high jumpers in the 2005 World Championship (4.61 $m.s^{-1}$, 4.39 $m.s^{-1}$, 4.18 $m.s^{-1}$),but The Egyptian high jumper's vertical velocity of CM at end take off (V_{y1}) is slower than what were seen in the jumpers in the 2005 World Championship (table 4,5).

The amount of vertical velocity at the end of the take-off phase largely depends on the jumper's horizontal velocity in last two strides of run up phase (Dapena, 2006; Čoh.M & Supej. M ,2008).

According to some studies on the high jump event, the vertical velocity of the CM at the end of the take-off phase is negatively related with the horizontal velocity of the CM at the start of the take-off phase. During the take-off phase, the horizontal velocity of the jumper's CM decreases the most and the strongest ground reaction force develops. This was the same what happened with our athletes, at the start of take-off, the horizontal velocity were (4.16 $m.s^{-1}$, 4.27 $m.s^{-1}$, 4.36 $m.s^{-1}$) then it decreases down to (2.08 $m.s^{-1}$, 2.11 $m.s^{-1}$, 2.49 $m.s^{-1}$). The consequence of the reduced horizontal velocity is an increase vertical velocity, which determines the height of the flight trajectory of the jumper's CM. And reference to our athletes, we can note that, the horizontal velocity of CM at start take off (V_{x1}) decreases from (4.16 $m.s^{-1}$, 4.27 $m.s^{-1}$, 4.36 $m.s^{-1}$)to (2.08 $m.s^{-1}$, 2.11 $m.s^{-1}$, 2.49 $m.s^{-1}$) at the end of the take-off phase, and the vertical velocity of CM at the start of the take-off phase increases as:

Velocities / Athletes	From $m.s^{-1}$	To $m.s^{-1}$
Athlete (A_1)	-0.08	4.85
Athlete (A_2)	-0.20	3.96
Athlete (A_3)	-0.21	3.71

Also, it happened in the jumpers in the 2005 World Championship. The horizontal velocity of CM at start the take-off decreases from (7.99 $m.s^{-1}$, 7.36, 7.59 $m.s^{-1}$) to (4.35 $m.s^{-1}$,3.75 $m.s^{-1}$, 4.31 $m.s^{-1}$) at the end of the take-off phase, and the vertical velocity of CM at the start of the take-off phase increases as:

Velocities / Athletes	From $m.s^{-1}$	To $m.s^{-1}$

Athlete (A_4)	-0.45	4.61
Athlete (A_5)	-0.34	4.39
Athlete (A_6)	0.45	4.18

Also, one study found a strong positive relationship between the horizontal velocity at the start of the take-off phase (V_{x1}) and the vertical velocity of CM at the end of the take-off phase (V_{y2}), which corresponds well to our study where we can see the strong negative relationship (V_{x1}) and (V_{y2}) (Dapena, et al, 1990).

In fact, the transformation is mainly due to the torque situation. The take-off point can be regarded as the center of rotation around which the CM revolves due the appropriate ground reaction force. The distance between the CM and the foot is considered the “lever arm” this is what causes the transformation of horizontal velocity into vertical velocity (Dapena, 2006; Čoh.M & Supej. M, 2008).

4.2.3. 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).

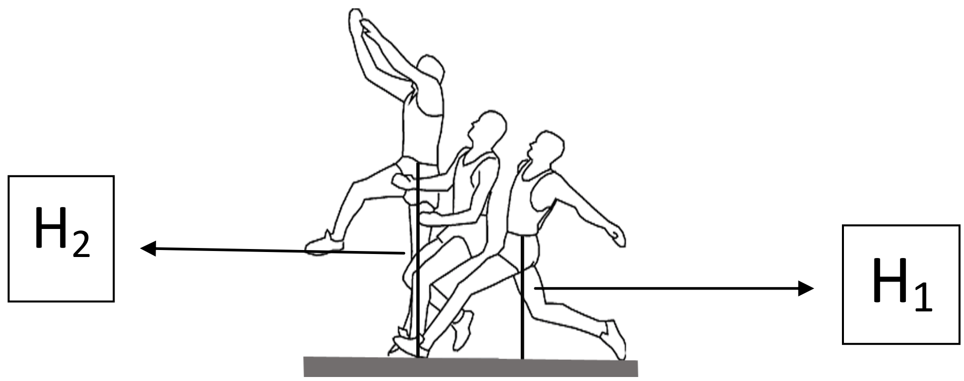
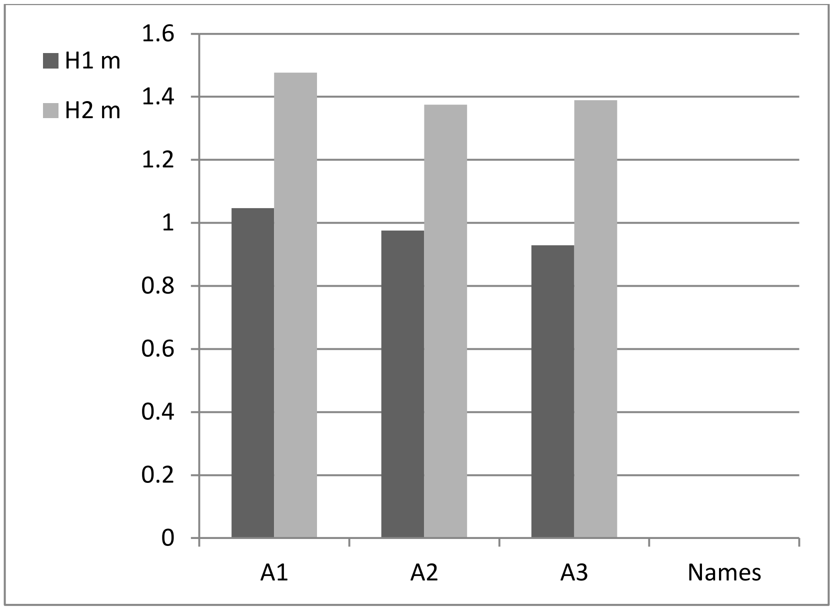


Figure 25: The height CM at start and end of take-off phase (Swedan, 2007)

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



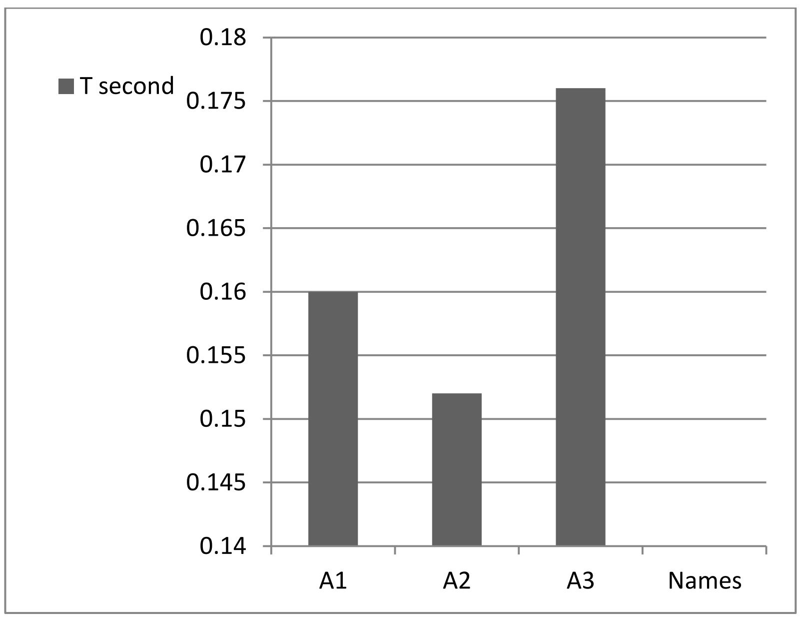


Figure 26: Chart of the height of CM and take-off time of the Egyptian high jumpers

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 2005 IAAF World Championships in Athletics (1.10 m, 1.01 m, 0.98 m and 1.40 m, 1.45 m, 1.40 m respectively). 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 2005 IAAF World Championships in

Athletics (0.180 s, 0.192 s, 0.148 s, respectively). (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).

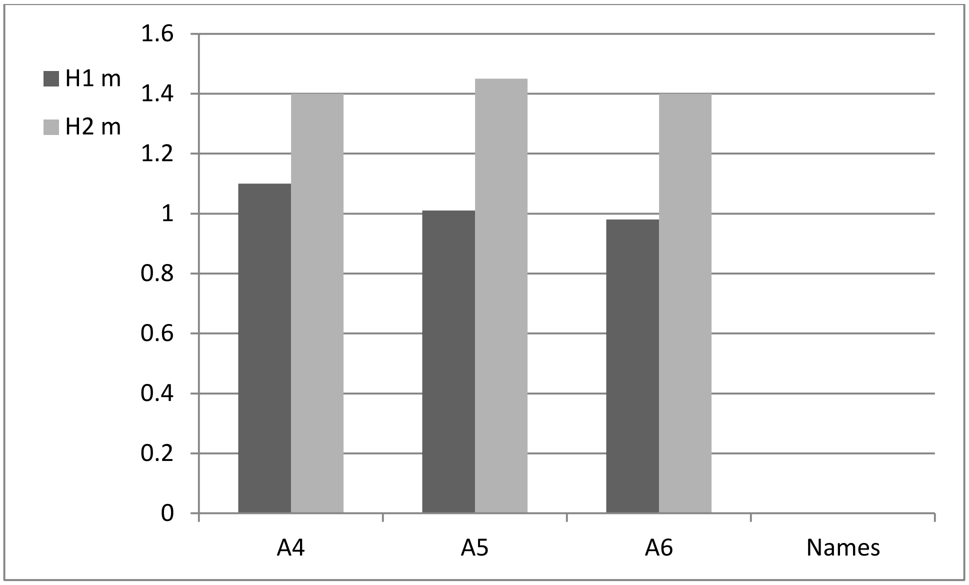
Of the three factors which contribute to successful high jumping, the distance CM can be lifted from take-off to peak of the jump (the result of a good take-off) is by far the most important. However the height of CM at take-off actually contributes the most to the jump – about two thirds among experienced 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).

Jumpers / Kinematic parameters	Unit	Athlete (A_4)	Athlete (A_5)	Athlete (A_6)
Height of CM at start of take-off (H_1)	m	1.10	1.01	0.98
Height of CM at end take off (H_2)	m	1.40	1.45	1.40
Take off time (T)	s	0.180	0.192	0.148

Table (7): The height of CM and take-off time of high jumpers at 2005 IAAF World Championships in Athletics



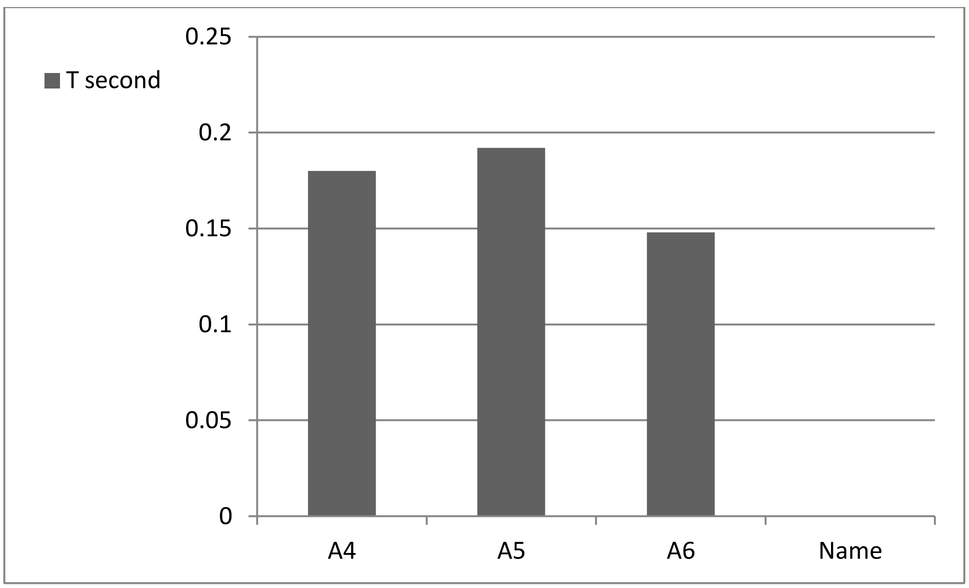


Figure 27: Chart of the height of CM and take off time of high jumpers at 2005 IAAF World Championships in Athletics

Motions in final part of the approach and take off phase

The motions from before the touchdown of penultimate stride to the instant of take-off for the best jumps of three jumpers covered by this report:

Athlete (A_1)

Athlete (A_1) strongly inclines his body, especially the trunks forward in the penultimate stride and probably also in the 3rd to last stride. This is very different from athletes (A_2, A_3). Athlete (A_1) raises his trunk and body during the last stride to prepare for his strong take off. At the instant of take-off foot touchdown, his backward lean of the body and the take-off leg is substantial, although the backward trunk lean looks a little less than other jumpers. His double-arm swing, almost vertical body at take-off, and the highly raised thigh of the swing leg reveal his technique to be good. Although cycling his legs before the crossbar clearance is his most notable characteristic, we know that how high the CM is raised is determined by take-off motion.

Athlete (A_2)

Athlete (A_2) exhibits a textbook orthodox technique with a double arm swing from a pronounced backward lean of the body at the touchdown of take-off foot. From the video, we see that he inclines his body forward appropriately in the penultimate stride. He raised his trunk, lowers his CM and prepares his arms for the double-arm swing in the penultimate and last stride, although his knee is less flexed than what we saw with athlete (A_1). In the take-off phase, athlete (A_2) inclines his take-off leg and trunk backward and swings his arms and swing leg in a wide range of motion. From the video, his inward lean of the body during the penultimate stride is as good as athlete (A_1) but he changes the direction of his progression acutely during the support phase. At the touchdown of the take-off foot, his inward lean is maintained.

Athlete (A_3)

Athlete (A_3) , who cleared 2.00m , uses a so-called a semi double arm swing and demonstrates good from similar to athlete (A_2), although a little more upward movement of his body is observed in penultimate stride. In last stride, he floats his body, as seen in the penultimate stride, which may have caused a little delay in the touchdown of take-off foot and caused a slapping of the foot down on the ground. From the video, his inward lean of the body in the penultimate stride is very pronounced but it becomes less so at the instant of touchdown of take-off foot.

5. 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.

6. 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. At the end, 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.

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Appendix

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 length
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)

Camera (1), athlete (A_3)

Camera 2, athlete (A_3)

Camera (1), athlete (A_2)

Camera (2), athlete (A_2)

Camera (1), athlete (A_1)

Camera (2), athlete (A_1)

Symbols and abbreviations:

DLT = the Direct Linear Transform

TO = Touch off

3D = three dimensional

TD = touch Down

2D = two dimensional

GCS = Global Coordinate System

LCS = Local Coordinate System

CM = Center of Mass

V_Y = Vertical Velocity

V_{Y1} = Vertical Velocity at Start of Take-off

V_{X1} = Horizontal Velocity at Start of Take-off

V_{Y2} = Vertical Velocity at end of Take-off

V_{X2} = Horizontal Velocity at end of Take-off

H_1 = Height of CM at start of Take-off

H_2 = Height of CM at end of Take-off

A_1 = Frist Athlete

A_2 = Second Athlete

A_3 = Third Athlete

A_4 = Fourth Athlete

A_5 = Faith Athlete

A_6 = Sixth Athlete

T = Time of Take-off

V_X = Horizontal Velocity

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