Kinematic Outcomes During the Takeoff Phase and Their Relations with the Digital Level of the Long Jump

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Introduction and Research Problem:

The current era is witnessing a major boom in various fields, particularly in sports, thanks to technical and technological progress that has contributed to the development of methods for monitoring and analyzing the movement of athletic performance. Athletics in general, and the long jump competition in particular, are activities that require the precise application of movement analysis methods. This aims to raise the physical and skillful levels of players, thereby enhancing their ability to achieve outstanding performances and advanced levels.

Kinematic analysis is the science based on measuring angles, distances, times, and trajectories to develop various athletic skills.

Kinematic analysis has significantly contributed to achieving success by linking human movements to athletic performance to improve the movement process in athletic performance.(3 : 28)

Theoretical observation is the most widely used method for kinematic analysis of human movement mechanics, relying on information gained when observing an athlete's movement for a particular skill. Coaches must base their ideas on the basic daily foundations so that their analysis does not become random. It must also be planned, and this is the role of the analyst, who has extensive experience in kinematic analysis. Therefore, qualitative analysis should not rely on self-evaluation of movements, but rather on both quantitative and qualitative analysis .(7 : 56)

Muayyad Amin (2019) explains that the field of motor performance analysis is one of the most important fields that relies on biomechanics to measure and interpret results and information about motor performance, particularly for athletes. This is to achieve several goals, including improving performance, avoiding injuries, and identifying performance defects and errors .(8 : 11)

Hussein Mardan and Iyad Abdul Rahman (2011) state that kinetic analysis is based on measuring angles, distances, times, and paths for the purpose of developing skills. Biomechanics is closely linked to sports training through Newton's third law and the law of gravity, which are essential for understanding motor performance and are therefore suitable for describing movements. He believes that one of the purposes of

biomechanics in the field of sports is to develop appropriate mechanical models for the purposes of education and training.(3:11)

Reaching the highest levels is an important matter that requires knowledge of the most important mechanical variables that contribute to mastering the skill, as well as performing the movement with economical effort. Reaching a good level of skillful performance requires knowledge of the precise details of the movement, its causes, and the form that distinguishes it. Therefore, Analysis is a logical method by which the phenomenon under study is approached as if it were divided into its constituent parts or elements. These procedures are examined separately to achieve a deeper understanding of the phenomenon as a whole(5:47) .

The long jump competition is one of the competitions that requires special specifications, abilities, and preparation from players. It has witnessed a clear and noticeable development in its record numbers, as well as in the ability of players to raise the numerical or technical level of performance in world championships or the Olympic Games. This has led many coaches to pay great attention to applying the laws of biomechanics to motor performance in a way that ensures the proper utilization of human capabilities and the achievement of the highest level of performance. Among the most important mechanical characteristics affecting the long jump competition are (takeoff speed, takeoff force, takeoff angle, and takeoff height). These characteristics are among the main determinants that influence the length or shortness of the jump distance as a result of the technical stages of this competition(11:666) .

Jump events are considered single, three-phase movements, with the approach generally being the preliminary phase, the take-off the main phase, and the final phase thereafter. Therefore, when studying any type of jumping event, it is important to first examine the general principles of performance in jumping events, and then discuss the technical stages of the event in question, which is the long jump(1:259) .

Jump-off represents the most important stage of motor performance in jumping in general. This stage produces the propulsive force for the jump, which is the result of the work of many muscle groups in the body, particularly the work of the muscles that support the take-off leg and the muscles that swing the free leg and arms during take-off. This force is equal to and opposite to the ground's reaction force. The coordination between approach and take-off plays a fundamental role in determining the magnitude of the athlete's launching motion, the angle of take-off, and the path of his center of gravity. From a mechanical perspective, "for every action there is an equal and opposite reaction". Thus the force acts in the vertical direction, and the ground resistance force also acts in the vertical direction. In order for the ascent to be effective, the ground resistance force and the friction force must be at most less than the resultant reaction of the ground to the force of the working muscles. Thus, the angle of ascent plays a positive role in the process of directing the body at the moment of ascent, and thus explosive force represents an important and essential element of the ascent process. (2:261)

Through the researcher's review of numerous previous Arab and foreign references and studies that addressed the biomechanical analysis of the long jump, such as the studies of Muhammad al-Husayni Muhammad **(2024), Dareen Tariq Muhammad Salah al-Din (2022), Ziad Saleh Ali (2019), and Mustafa Bousheiba (2019).**

Through the researchers' work, their understanding of the problem, and their theoretical readings, they believe that the long jump is one of the athletics competitions that requires a great deal of integration between various physical and skillful abilities, given their significant role in achieving numerical success in many different events and competitions.

The ascent phase is one of the important and fundamental stages that contribute to achieving this achievement. It is the decisive factor in determining the achieved jump distance. This phase is characterized by being the most influential in converting the horizontal speed acquired during the approach into an appropriate vertical height that ensures the player reaches the best possible distance. Therefore, studying the kinematic variables during the ascent phase Jumping is essential for understanding the nature of motor performance and identifying the factors influencing it.

Although the sports field has witnessed tremendous progress in the field of motor analysis, there are still shortcomings in studies that address the relations between the kinematic outcomes of the jump-off phase and the actual numerical level of long jumpers. Hence, the problem of the current research arises in an attempt to uncover the nature of this relation, with the aim of identifying the most important kinematic outcomes that

contribute to improving numerical level. This will help coaches direct training programs in a scientific manner that contributes to developing performance and achieving the best results.

Research Objective:

The research aims to:

- Study the kinematic outcomes during the jump-off phase for long jumpers.

- Identify the extent of the relations between the kinematic outcomes of the jump-off phase and the numerical level of the long jump.

Research Questions:

1- What are the kinematic outcomes during the jump-off phase for long jumpers?

2- Is there a statistically significant correlation between each of the outcomes? What are the kinematics of the take-off phase and the level of advancement in the long jump?

Research Methodology:

The researchers used the descriptive approach due to its suitability for the nature of the research.

Research Community:

The research community includes the Egyptian national long jump team players for the 2024-2025 sports season.

Research Sample:

The researchers intentionally selected the research sample from the Egyptian national long jump team players for the 2024-2025 sports season, totaling (6) players. Table (1) shows the technical description of the players under study.

Table (1)

Statistical description of the players in the primary research sample according to their anthropometric variables

sample	age	Hight	weight
Average	19,61	1,77	72.12
Stander Deviation	0.57	0.06	3.70

Sample Characteristics:

- Players must be members of the Egyptian long jump national team.

- They must have at least 7 years of training experience.

Data Collection Methods:

1- Tools and Equipment Used for Anthropometric Measurements:

- A rheostat to measure height (cm).

- A calibrated digital medical scale to measure weight (kg).

- A player data registration form.

2- Tools and Equipment Used for Filming:

- (3) 100-frame-per-second video cameras.

- (3) tripods equipped with a water balance.

- Adhesive phosphorous markers to be placed around the body's joints.

- (1) calibration unit consisting of three rigidly intersecting iron beams, each 1 m long and divided into 18 points measuring 5 x 5 cm, divided into (3) levels (lateral, frontal, and horizontal).

3- Procedural Steps for Filming:

- The study was conducted at the athletics field at the Olympic Center for National Teams in Cairo.

- The researchers recorded the athlete's weight and height measurements.

- The filming field was equipped with guide markers and a scale was set up for the analysis.

- The camera (video recording camera) was positioned perpendicular to the spatial plane where the skill under study was performed, at a height of 1.50 m.

- The players were equipped with clothing appropriate for filming.

- Reflective (control) markers were placed on the anatomical joints of the athlete's body.

- The researchers ensured that the camera was positioned appropriately, along with the appropriate filming angles, and that the athlete's skillful performance and guide markers could be seen on the video processing unit.

- The filming process was ensured.

4- Motion Analysis Program:

The researchers performed motion photography and analysis using the motion analysis program (Skill Spector). This program was designed to track and analyze movement. The researchers used this program for several reasons, the most important of which are the following:

- The program operates using a protection unit connected to a computer, which increases the accuracy of the recorded and saved data.
- It can be photographed from inside halls and open spaces.
- It can be analyzed using one or more cameras.
- It features instant recording of movement without interruption during performance.
- It features the accuracy of the extracted results.
- The movement of the body as a whole or a single body part can be analyzed.
- The analysis is carried out in two dimensions (2D) or three dimensions (3D).
- It features multiple kinematic indicators extracted by the program, which are as follows:
- Linear variables (displacement, velocity, acceleration).
- Angular variables (angles, angular velocities, angular accelerations).).
- Determine the center of gravity of the body and its connections (displacement – speed – acceleration).
- Extracting the selected mechanical properties in a digital image.

Fifth: Steps to carry out the research:

- **Exploratory study:**

The researchers conducted the study on the exploratory sample using the kinetic analysis program. The exploratory study was conducted on Sunday, 6/15/2025 AD, in the athletics arena at the Olympic Center in Cairo, with the aim of implementing the following:

- Choose the appropriate timing for filming.
- Preparing the necessary equipment to conduct the biomechanical analysis process.
- Preparing cameras for the photography process.
- Methods of adjusting cameras and coordinating and organizing the workflow during measurement.
- Determine the distance of the camera from the level and height of the movement, while filming the skill.
- Installing guiding signs on the player's body and making them clear.
- Identify the obstacles that may occur before conducting the basic experiment, and work to solve them. The following figure shows the location of filming:

Results of the survey:

The exploratory study yielded several results, the most important of which are the following:

- The appropriate time for filming was chosen, which was in the afternoon.

 The necessary equipment was prepared for the biomechanical analysis.

 The cameras for the filming process were set up.

 The cameras were adjusted, and the workflow during the measurement was coordinated and organized as follows:

1- Camera No. (1) was perpendicular to the player's lateral plane.

2- Camera No. (2) was perpendicular to the player's frontal plane and in front of the jump pit.

3- Camera No. (3) was located midway between cameras (1) and (2) at a 45-degree angle.

The Main Study:

1- The long jump skill of the players under study was filmed according to several steps, as follows:

A- Preparing the Filming Location:

According to the results of the exploratory study, the researchers reached the final procedures for the filming location, determining the range of motion for the skill, preparing the calibration box and the filming area in which the cameras would be placed, and ensuring adequate lighting.

B- Preparing the Camera:

During this phase, the following was done:

1- Ensure that cameras are placed in the appropriate manner.

2- Preparing the cameras for the motion analysis unit

3- Ensure that the cameras work synchronously.

4- Place the calibration box.

5- Install the cameras on the stand.

6- Ensure that the photographic angles used facilitate the ability to see the player in all his details when performing.

C- Player preparation:

1- The researchers placed photographic guide marks on the joints of the players' bodies under study.

2- Players wear appropriate sports clothing for filming so that the anatomical points are visible in the filming.

3- Assemble the skill correctly before starting to film.

4- Make sure to give instructions to the players before performing each attempt.

5- Re-install the guideposts between one attempt and the next.

6- Ensure that the player stands at the starting point of the performance before each attempt (the location of the calibration box).

D- Conducting the basic study:

After ensuring that the objectives of the exploratory study (photography) were achieved, Saturday, 6/28/2025 AD, was set at the athletics field at the Olympic Center in Maadi to conduct the basic study of the skill (recording Research) by using the Skill Spector program for motion analysis, and it was photographed The skill (under investigation) was given three experimental attempts for each player. After ensuring that the player was performing the skill in the optimal position, the researchers

filmed the required number of attempts. Between each attempt, there was an appropriate rest period to allow the player to regain their energy for qualitative and quantitative analysis of the skill.

Sixth: Statistical Methods Used:

- Arithmetic Mean
- Standard Deviation
- Pearson Correlation Coefficient
- Percentage

Presentation, Interpretation, and Discussion of Results:

Presentation, Interpretation, and Discussion of the Results of the First Question:

1- What are the kinematic outcomes during the take-off phase for long jumpers?

Table (2)

Arithmetic Mean and Standard Deviation of the Kinematic Outcomes of the Take-off Phase for Long Jumpers (n = 6)

Phase	Unit of Measurement	Player 1	Player 2	Player 3	Player 4	Player 5	Player 6	Mean	± SD
Take-off Range	**cm**	0.76	1.00	0.84	0.99	**1.30**	0.97	0.98	0.18
Entry Speed T,D	**m/s**	6.31	7.30	8.27	7.51	7.36	6.74	7.25	0.67
Exit Speed T,T	**m/s**	6.28	7.05	6.29	6.99	6.20	5.47	6.48	0.58
Average Speed	**m/s**	**6.30**	7.40	7.28	7.25	6,78	6.11	6.85	0.55
Exit Speed Loss from Entry Speed	**m/s**	0.03	0.25	1.98	0.52	1.16	1.27	0.87	0.73
Moment of Entry and Take-off Height	**m**	0.80	0.77	0.78	0.80	0.74	0.72	0.77	0.03
Take-off and Height	**m**	0.98	1.04	0.96	0.94	0.89	0.98	0.95	0.06

The results of Table (2) show that there is a variation in the extent of the players' ascent, as the percentages of the players' ascent extent ranged between (0.76: 1.30 m) with a general average of (0.98) and a standard deviation of (0.18). The average entry speed of the players ranged between (6.31: 8.27 m/s) with an arithmetic mean of (7.25) and a standard deviation of (0.67). The players' exit speed ranged between (5.47: 7.05 m/s) with an arithmetic mean of (6.38) and a standard deviation of (0.58), while the average difference between the exit speed and the entry speed ranged between (0.03: 1.89) with an arithmetic mean of (0.87) and a standard deviation of (0.73). The average CG rise at the moment of entry also varied between the players, reaching between The mean CG height at the moment of takeoff ranged from 0.89 to 1.04, with a mean of 0.95 and a standard deviation of 0.06.

The researcher attributes the difference in the players' takeoff range to their ability to convert horizontal velocity into vertical height at the moment of takeoff. This is closely related to the players' high level of explosive leg power, which positively impacts takeoff angles and performance technique during the propulsion phase.

The researcher also attributes the difference in entry and exit velocity values during the takeoff phase to the fact that most players have a high level of speed, which is generated significantly before takeoff. This enhances horizontal propulsion, thereby increasing the length of the jump. Conversely, a player may intentionally reduce their approach speed to increase flight accuracy or compensate for weak technical skills. The researcher also attributes the clear variation in the exit amplitude after the takeoff to the loss of speed between entry and exit. This result is a

natural consequence of converting a portion of horizontal speed into vertical height. However, this loss varies from one player to another, indicating that some players retain a significant portion of their speed during the transition, while others suffer a significant loss of kinetic energy. This loss may be a result of poor muscle coordination during that moment.

This result is consistent with the results of studies by **Muhammad al-Husayni al-Mutawali (2024), Dareen Tariq Muhammad Salah al-Din (2022), and Ziad Saleh Ali (2019),** which indicated that there are several kinematic outcomes that have a clear impact on the takeoff phase of the long jump.

Presentation, interpretation, and discussion of the results of the second question:

2- **Is there a statistically significant correlation between the kinematic outcomes of the takeoff phase and the level of the long jump?**

Table (3)

Correlation coefficients between the kinematic outcomes of the take-off phase and the digital level for the long jump (n = 6)

Phase	Unit of Measurement	coloration
Take-off Range	**Cm**	0.81
Entry Speed T,D	**m/s**	0.90
Exit Speed T,T	**m/s**	0.72
Average Speed	**m/s**	0.88
Exit Speed Loss from Entry Speed	**m/s**	0.77
Moment of Entry and Take-off Height	**M**	0.94
Take-off and Height	**M**	0.68

The results of Table (3) reveal the following:

- There is a statistically significant direct correlation between the kinematic outcomes of the take-off phase and the numerical level of the long jumpers under study.

The researcher attributes the existence of a statistically significant direct correlation between the kinematic outcomes of the take-off phase and the numerical level of the long jumpers under study to this logical result, especially with regard to the take-off phase. During this phase, a portion of the horizontal velocity is converted into a vertical component, while maintaining the horizontal component of the velocity as much as possible. Therefore, the appropriate take-off angle, the more balanced the angle, the more it helps achieve the best balance between height and horizontal flight, which is reflected in the total jump distance. Furthermore, increasing the value of horizontal and vertical velocity at the moment of separation leads to increased flight time and, consequently, increased distance covered. The higher the center of gravity during takeoff, which is appropriate for the direction of movement, contributes to improving the overall distance, in conjunction with the propulsive force and contact time. Increasing propulsive force while reducing the time the foot rests on the takeoff pad leads to greater efficiency in force transfer and, consequently, an increase in the numerical level.

Conclusions and Recommendations:

First: Conclusions:

1- There was a variation in the entry and exit speeds of the players during the takeoff phase, with the average entry speed ranging between 6.31 and 8.27 m/s, with an arithmetic mean of 7.25 m/s and a standard deviation of 0.67.

2- The average exit velocity during the same phase for the players under study ranged between (5.47: 6.99 m/s), with an arithmetic mean of (6.38 m/s) and a standard deviation of (0.58). Therefore, the velocity loss between the exit and entry for the players under study during the take-off phase ranged between (0.03: 1.98 m/s), with an arithmetic mean of (0.87) and a standard deviation of (0.73).

3- There is a direct correlation between the kinematic outcomes of the take-off phase and the numerical level of the long jump.

Second: Recommendations:

1- The need to focus on training in the stages of the long jump, especially the take-off phase, due to its significant role in achieving numerical achievement.

2- The need to focus on kinematic analysis of the various stages of the long jump, which contributes to improving their numerical level.

3- The need to draw on the results of current research in training long jumpers in a way that contributes to improving their numerical level.

4- The need to train to increase and improve the numerical level of long jump performance for different players.

5- The need to conduct more studies and research on long jump skill among other samples.

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