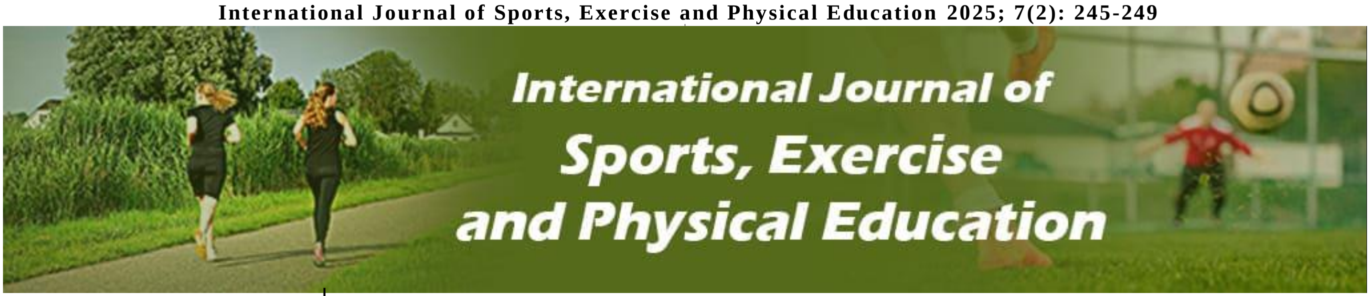

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Analysis of selected kinematic variables in the take-off phase of the long jump for female athletes under 18 years

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Abstract
Motion analysis has become an issue of growing concern in the sphere of the physical education and sports sciences as the means of improving performance results in the various specializations. The objective of the present study was to examine certain kinematic parameters with respect to long jump take-off in female athletes below the age of 18 years. The variables measured were; take-off time, take-off distance, take-off speed, take-off angle, maximum height taken off, and final performance. Besides, the study aimed at establishing the relationships between these variables and the overall performance of the athletes. The hypothesis stated that there are major correlations between the variables of kinematics and long jump performance of junior athletes. The population of research was the top four junior Iraqi females that were the jumpers in the final round of the Iraqi Championship between the clubs and institutions. All of the participants had six attempts; therefore, the total number of trials was 24, and 20 valid jumps were analyzed, removing the cases of unsuccessful attempts. The relationship between take-off time and take-off angle and final performance were found to be inversely correlated; direct correlations were found between the take-off distance, take-off speed, maximum height attained and overall achievement. According to these results, the study suggests that coaches should make use of these kinematic parameters in the daily training programs and use motion analysis as a diagnostic method to optimize the mechanical variables that affect performance.

Keywords: Kinematic analysis, long jump, biomechanics, athletics

Introduction

Achieving superior athletic performance has always been a primary objective in sports sciences. To this end, researchers continuously seek innovative approaches that contribute to peak achievement, whether through theoretical knowledge or practical applications. The modern era, characterized by rapid scientific and technological progress, has enriched the field of athletics by integrating multiple scientific disciplines such as biomechanics, physiology, and anatomy into training methods.

Biomechanics, in particular, provides valuable insights by applying anatomical principles and mechanical laws to athletic movements. A central branch of biomechanics is kinematic analysis, which measures angles, distances, times, and trajectories to refine athletic skills and enhance performance efficiency (Mardan & Abdulrahman, 2011) [6].

Within track and field, the long jump is one of the most demanding events, requiring precise coordination of technical stages: approach, take-off, flight, and landing. Each phase contributes to the final performance and is influenced by physical and biomechanical factors. Thus, investigating the take-off phase where vertical and horizontal forces converge offers vital knowledge for improving athletic achievement.

The research problem centers on understanding the significance of kinematic variables in the take-off phase and whether their interrelationships can explain variations in long jump performance among junior female athletes. Accordingly, this study focused on analyzing six critical kinematic parameters and examining their correlations with final achievement.

The study was conducted at the College of Physical Education and Sports Sciences, University of Baghdad, between November 15, 2024, and July 30, 2025, using a purposive sample of elite female athletes under 18 years.

Methodology and Procedures

The study employed the descriptive method with a survey approach, supplemented by correlational analysis to explore the relationships among kinematic variables. The research population was selected intentionally and consisted of four elite female athletes under 18 years, who achieved the highest results in the Iraqi Clubs and Institutions Championship (second round) held in Erbil Governorate, Franso Hariri Stadium, 6-9 November 2024. These athletes were also nominated for external qualification in the Arab Tournament and the West Asian Championship.

Exploratory Trial

An exploratory experiment was conducted on Friday, April 4, 2025, at the Salim Al-Awadi Forum/Al-Bayaa with the same research sample. This preliminary stage aimed to ensure accuracy in the following aspects:

1. Determining the optimal placement and distance of cameras relative to the performance area, as well as setting appropriate camera speed.
2. Estimating the total time required to conduct the test.
3. Verifying the reliability of instruments and tools used in data collection.
4. Assigning specific roles and responsibilities to the supporting staff.
5. Checking memory card readiness and ensuring sufficient storage capacity.
6. Identifying the appropriate number of frames per second in relation to the athletes' movement speed.

Main Experiment

The main trial took place on Friday, April 11, 2025, at the College of Physical Education and Sports Sciences Stadium, University of Baghdad/Al-Jadriya. The experiment consisted of the long jump achievement test (IAAF, 2019) [4], which is an official standard for selecting members of the national junior team to represent Iraq in upcoming international competitions, including the Arab Tournament (Tunisia) and the West Asian Championship (Bahrain).

A CASIO FH13.5 analysis camera was used, positioned 5 meters away from the performance field at a height of 1.2 meters, operating at 120 frames per second and perpendicular to the motion plane. The following kinematic variables were extracted using the Kenova analysis program:

- Take-off time
- Take-off distance
- Take-off speed
- Take-off angle
- Maximum height achieved
- Final achievement

Data processing was performed using SPSS (version 24) to compute the arithmetic mean, standard deviation, skewness coefficient, correlation coefficients, t-values, and F-values.

Video Analysis: The Video Cutter software was initially employed to isolate each attempt for all participants and exclude unsuccessful trials. The validated clips were then imported into the Kenova program for motion analysis.

1. Definition of Take-Off Distance

Take-off distance is defined as the displacement of the body's center of mass during the transition from the initial ground contact of the take-off foot until its final separation from the ground (Figure 1).

Fig 1: shows the ascent distance.

2. Climbing time

Ascension time is defined as the duration required for the body's center of mass to move from the initial ground contact of the take-off foot until its complete separation from the ground, as illustrated in Figure (2).

Fig 2: shows the ascent time.

3: Speed of ascent

It is the distance confined to the transfer of the center of mass of the body between the beginning of the first support of the foot of ascent until it leaves the ground in the time confined to the same distance, as shown in Figure (3).

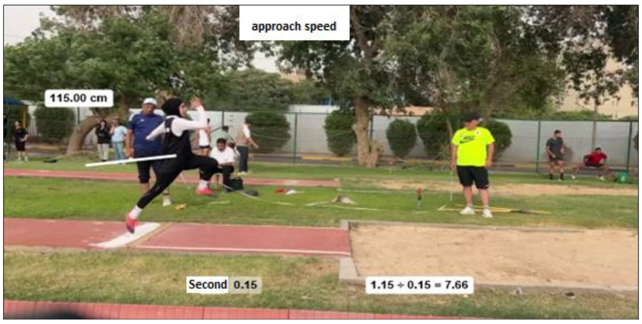

Fig 3: Shows the speed of ascent.

4. Elevation angle

It is the angle enclosed by the transfer of the body's center of mass between the horizontal line and the vertical line extending from the hip joint to the shoulder joint, as shown in Figure (4).

Fig 4: Shows the angle of elevation

5. Maximum height achieved

It is the actual distance achieved for the transfer of the body's center of mass between the beginning of the first support of the ascent foot to the maximum possible flight arc, as shown in Figure (5).

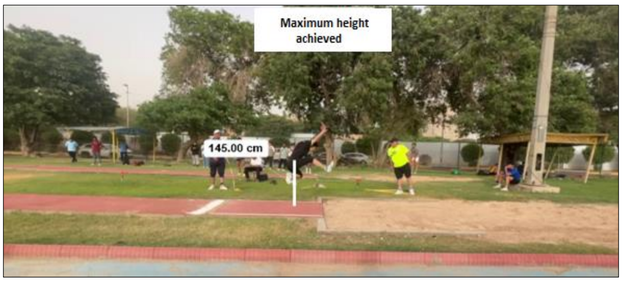

Fig 5: Shows the maximum height achieved

After the procedure Motion analysis process with the program Analysis (Kenova) to measure and analyze some mechanical determinants in the ascent stage (ascent time, ascent distance, ascent speed, ascent angle, maximum height achieved, final achievement), as well as to identify the correlational relationships between these variables and the achieved achievement, which the researcher believes is mediated by them It will lead to a logical and objective indicator of the sample's level of achievement and the results it produces. Here we will try to present these results and then discuss them and interpret their indicators according to achieving the research objectives. They were converted into graphic tables as an illustrative tool for the research. After unpacking the data obtained by the researcher from the test, the sample homogeneity process was carried out through the arithmetic mean, standard deviation and the value of the skewness coefficient, as well as conducting correlation coefficients between the variables and achievement in the research sample in the studied variables. To verify the validity of the research hypotheses, the researcher presented the results that were reached and discussed them and then interpreted the indicators of achieving the hypotheses. The results will be shown in Tables (1), (2), (3), (4), which show the arithmetic means, standard deviations and homogeneity between the sample individuals and the statistical coefficients and the matrix for correlational relationships.

Table 1: Shows arithmetic means and standard deviations.

Variable	Unit of Measurement	Mean	Standard Deviation
Climbing distance	meter	1.16	0.217
Time of ascension	second	0.151	0.088
Speed of ascent	meter/second	7.32	0.576
Elevation angle	degree	60.56	5.421
Maximum height achieved	meter	1.47	0.072
Final achievement	meter	4.17	0.590

Note: Values represent means ± standard deviations calculated from 20 attempts by four jumpers.

The results in Table (1) show the values of the arithmetic means and standard deviations of the research variables for the four competing jumping attempts, and the results are for twenty successful attempts.

Table 2: It shows the homogeneity of the sample individuals

T	Variable	Mean	Standard Deviation	Standard Error	Coefficient of Skewness	Flattening
1	Climbing distance	1.16	0.217	0.0876	0.783	0.611
2	Time of ascension	0.151	0.088	0.0754	0.544	0.822
3	Speed of ascent	7.32	0.576	0.0654	0.684	0.743
4	Elevation angle	60.56	5.421	0.0543	0.231	0.551
5	Maximum height achieved	1.47	0.072	0.0432	0.456	0.420
6	Final achievement	4.17	0.590	0.0321	0.292	0.349

Note: Results are based on 20 attempts to isolate the sample.

Show the results in Table (2) homogeneity of sample individuals Through the values of the coefficient of skewness and flatness, which were limited between (±1) Which indicates that it is within the moderate trend.

Table 3: Statistical transactions

T	Variable	Correlation Coefficient	t-value	F-value	Sig. value	Statistical Significance
1	Climbing distance	0.812*	2.624	12.042	0.009	Significant (moral)
2	Time of ascension	-0.821*	2.511	14.043	0.008	Significant (moral)
3	Speed of ascent	0.946**	3.225	16.012	0.000	Significant (moral)
4	Elevation angle	-0.925**	3.442	14.078	0.000	Significant (moral)
5	Maximum height achieved	0.756*	2.435	9.094	0.023	Significant (moral)

Note: Significant at degree of freedom (df) = 19 and significance level α ≤ 0.05.
Single asterisk () indicates significance at p ≤ 0.05; double asterisk (**) indicates higher significance (p ≤ 0.01).*

The results in Table (3) showed the values of the correlation coefficients, the t value, the f value, and the sig for sample individuals

Table 4: Shows the correlation matrix between achievement and kinematic variables

Variables	Climbing Distance	Time of Ascension	Speed of Ascent	Elevation Angle	Maximum Height	Achievement
Climbing Distance	1.000	0.812*	0.896*	0.923**	0.902**	0.915**
Time of Ascension		1.000	-0.821*	0.921**	0.912**	-0.920**
Speed of Ascent			1.000	0.946**	0.989**	0.876*
Elevation Angle				1.000	-0.925**	-0.888*
Maximum Height					1.000	0.756*
Achievement						1.000

Notes: •Correlation is significant at the 0.05 level (2-tailed): *• Correlation is significant at the 0.01 level (2-tailed): **

Discussion of Results

The correlation matrix presented in Table (4) revealed significant associations between several kinematic variables and the final performance in the long jump. Specifically, a direct significant correlation was found between ascent distance and overall achievement (r = 0.812*), while an inverse significant correlation was observed between ascent time and achievement (r = -0.821*). In addition, ascent speed demonstrated a strong positive correlation with achievement (r = 0.946**), whereas ascent angle showed a strong negative correlation (r = -0.925**). Finally, maximum height attained during flight was positively correlated with performance (r = 0.756*).

The researcher attributes these findings to the careful selection of kinematic variables that critically influence performance during the take-off phase, which is considered one of the most decisive technical stages of the long jump.

The star sign without the minus sign * means that there is a direct correlation in the positive direction.

(*) إشارة النجمة مع السالب *- تعني وجود علاقة ارتباط عكسية بالاتجاه السالب

The star sign with the minus sign *- means there is an inverse correlation in the negative direction.

(*) إشارة النجمتين بدون السالب ** تعني وجود علاقة ارتباط طردية عالية بالاتجاه الموجب

The two-star sign without the minus sign ** It means that there is a high direct correlation in the positive direction.

(*) إشارة النجمتين مع السالب **- تعني وجود علاقة ارتباط عكسية عالية بالاتجاه السالب

The two stars with the minus sign **- means there is a high inverse correlation in the negative direction.

Ascent Distance

The results indicated a direct relationship between ascent distance and performance. The researcher suggests that the greater the horizontal displacement of the center of mass achieved in a short time, the greater the velocity generated, thereby enhancing jump performance. This finding aligns with the view of Thompson (1996) [11], as cited by Qasim Hassan Hussein, who emphasized that the displacement of the center of mass is among the most influential variables in both horizontal and vertical jumps.

Ascent Time

An inverse correlation was found between ascent time and performance. The researcher interprets this as evidence that shorter ground contact time during take-off produces greater instantaneous force, which combined with horizontal displacement of the center of mass contributes to higher speed and more effective flight. This conclusion supports the perspective of Suleiman Ali Hassan *et al.* (1979) [3], who stated that time serves as a fundamental criterion for differentiating movement patterns and comparing athletes' performances.

Ascent Speed

Ascent speed exhibited a strong positive correlation with performance, indicating that higher speeds facilitate greater displacement within shorter take-off times, resulting in improved achievement. This agrees with Hassan *et al.* (1979) [3], who emphasized that speed, from a mechanical standpoint, represents the coordination between the displacement of the center of gravity and take-off, provided biomechanical principles are properly applied.

Ascent Angle

A strong inverse correlation emerged between ascent angle and performance. The researcher explains that the take-off angle is a pivotal determinant of flight performance. A smaller angle enhances horizontal distance, whereas a larger angle produces excessive vertical displacement at the expense of horizontal distance. Thus, the optimal angle balances vertical and horizontal vectors to maximize performance. This interpretation is consistent with the findings of Wissam Salah and Ahmed Youssef (2008) [8], who highlighted the importance of fluidity in motor performance, and with Janshen (2010) [5], who argued that increased trunk inclination and rapid arm movements enhance forward torque, improving horizontal propulsion.

Maximum Height

The highest center of mass of the body portrayed a direct correlation to achievement. This aspect, according to the researcher, when coupled with other determinants associated with kinematics is a major contributor of the overall jump distance as it secures the efficient trajectory. This finding is aligned with the conclusions of Shalash *et al.* (2023) [11] who highlighted that distance in track and field events is the interaction of applied force, speed of execution, and optimal timing.

Final Achievement

The combined effort to incorporate the mechanics in all the technical stages, namely, the approach, take-off, flight, and landing, was considered the reason behind the overall performance in the context of the long jump. The results are aligned to Shaghati and Ali (2012) [10], who emphasized that long jumpers should follow the principles of mechanics to realize coordination, timing, and smooth movement between the stages in order to optimize performance.

Finally, the hypotheses of the study were valid, achieving the relevant correlation level was achieved among the chosen variables of kinematic determinants and the ultimate success in the long jump that proved the critical role of the biomechanical factors influencing the success of an athlete.

Conclusions

1. Ascent distance showed direct influence on performance in the significant effect; the more the center of mass is horizontally displaced within the same time duration, the higher the final achievement in the long jump.
2. The take-off time showed that there was a remarkable negative relationship between performance and shorter contact at take-off increases the overall performance.
3. There was a strong positive correlation between Ascent speed and performance, which validated that increasing speeds produce direct proportional increases in the distances of the long jump.
4. There were strong negative relationships between take-off angle and performance, wherein the smaller the angle, the higher the horizontal displacement and hence the better results were.
5. Peak height of the center of mass showed a great positive effect on performance; the ability to gain higher vertical displacement adds up to increase in total jump distance significantly.

Recommendations

1. It is recommended that coaches should apply the results of this research in training programs because they would have practical implications in the enhancement of long jump performance, and also time and effort optimization.
2. More efforts in the use of kinematic analysis as a diagnostic tool to determine the strengths and weaknesses that cannot be observed using the naked eye should be emphasized, and the interpretation of data must be done by qualified specialists.
3. Future studies need to be conducted on other athletic events (i.e. triple jump, high jump and pole vault) to increase the relevance of biomechanical knowledge and improve the results of the corresponding competitions.
4. In training and research, mechanical variables need to be attended to and treated well scientifically since they are key contributors to the development of athletic performance.
5. Mechanism of activity Training programs must be based on scientific concepts and include the element of biomechanical and kinematic analysis to organize the training loads.

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