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Biokinetic Analysis of Arm Movement During the Shot Put and its Relationship to Throwing Distance Among Students

Muthanna Harith Ekrrayem

¹University of Samarra, Iraq

muthanna96@uosamarra.edu.iq

Correspondensi Author

Email: muthanna96@uosamarra.edu.iq

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ABSTRACT

This research aims to study the biomechanics of the shot put event and analyse the biomechanical variables influencing it, thereby providing coaches and athletes with an accurate scientific tool for performance evaluation and the identification of strengths and weaknesses. The shot put is an event that requires a high level of skill and physical fitness, particularly with the recent advancements in the use of modern imaging and analysis equipment. The research problem stems from the practical observation conducted by the researcher on students at the Faculty of Physical Education, which revealed a notable disparity in numerical results (distance achieved) in the shot put event, despite the relative similarity in the students' physical composition. Hence, the research objectives were to identify certain biomechanical changes associated with shot put performance, and the researcher hypothesised the existence of a statistically significant relationship between performance level and the biomechanical variables studied. The research methodology and field procedures were then addressed, with the researcher adopting a descriptive approach using correlational methods due to its suitability for the nature of the problem; the research sample comprised 12 fourth-year students. The results were then presented and discussed, leading to a set of conclusions and recommendations. The results showed a statistically significant correlation between the take-off angle, take-off speed, take-off height, and the level of performance in the shot put. Consequently, the researcher recommended that further similar studies be conducted on other track and field events, emphasising the importance of taking these variables into account during training and instruction

Keywords: Biokinetic; Arm movement; Shot put; Throwing distance.

ABSTRAK

Penelitian ini bertujuan untuk mempelajari biomekanik acara lempar peluru dan menganalisis variabel biomekanik yang mempengaruhinya, sehingga memberikan pelatih dan atlet alat ilmiah yang akurat untuk evaluasi kinerja dan identifikasi kekuatan dan kelemahan. Lempar peluru adalah acara yang membutuhkan keterampilan dan

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kebugaran fisik tingkat tinggi, terutama dengan kemajuan terbaru dalam penggunaan peralatan pencitraan dan analisis modern. Masalah penelitian berawal dari pengamatan praktis yang dilakukan oleh peneliti terhadap mahasiswa di Fakultas Pendidikan Jasmani, yang mengungkapkan adanya perbedaan yang mencolok dalam hasil numerik (jarak yang dicapai) dalam acara lempar peluru, meskipun relatif mirip dalam komposisi fisik mahasiswa. Oleh karena itu, tujuan penelitian adalah untuk mengidentifikasi perubahan biomekanik tertentu yang terkait dengan kinerja lempar tembakan, dan peneliti berhipotesis adanya hubungan yang signifikan secara statistik antara tingkat kinerja dan variabel biomekanik yang dipelajari. Metodologi penelitian dan prosedur lapangan kemudian ditangani, dengan peneliti mengadopsi pendekatan deskriptif menggunakan metode korelasional karena kesesuaiannya dengan sifat masalah; Sampel penelitian terdiri dari 12 mahasiswa tahun empat. Hasilnya kemudian disajikan dan didiskusikan, yang mengarah pada serangkaian kesimpulan dan rekomendasi. Hasilnya menunjukkan korelasi yang signifikan secara statistik antara sudut lepas landas, kecepatan lepas landas, tinggi lepas landas, dan tingkat kinerja dalam lemparan peluru. Akibatnya, peneliti merekomendasikan agar studi serupa lebih lanjut dilakukan pada acara lintasan dan lapangan lainnya, menekankan pentingnya mempertimbangkan variabel-variabel ini selama pelatihan dan instruksi

Kata Kunci: Biokinetik; Gerakan lengan; Tolak peluru; Jarak lemparan.

INTRODUCTION

Scientific progress in training methods and player preparation is one of the key aspects on which sporting advancement focuses, as it represents the ultimate outcome of utilising all other sciences (Nagorna et al., 2024). Motor performance serves as a mirror reflecting players' ability to understand the components and elements of movement. Interest in studying human motor performance in various sporting activities, as well as the motor skills associated with these activities, has become a key concern for those involved in teaching and coaching these skills, in order to examine the factors influencing motor performance directly or indirectly (Kokstejn et al., 2019; Kokstejn & Musalek, 2019). Therefore, coaches, teachers and those interested in the field of sport need to understand the mechanism of the human musculoskeletal system and its components, in order to develop performance levels in sport in general and in specialised activities in particular; as this requires a holistic view of the various phenomena of life and the diverse forces they contain that affect the human musculoskeletal system, which is expected to be highly efficient in overcoming and positively managing these forces so that movements are performed with the utmost effectiveness in performance, aiming for precision in pursuit of better technique. It is one of the means of precise knowledge of the movement trajectory with the aim of improvement and development (Kjaer et al., 2015; Sugimoto et al., 2009; Watkins, 2014).

As for the effectiveness of the shot put throw and how kinetic momentum is transferred from the torso to the throwing arm, the arm plays the role of the 'final guide' and is directly responsible for applying force in the final moments before release. Biokinematic analysis of arm movement reveals critical variables, the most important of which are the launch angle, the height of the release point, and the initial velocity of the shot put (Meron & Saint-Phard, 2017; Schofield et al., 2022). When studying the

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performance of college students, we find a notable variation in the distances achieved, which is often due to a lack of kinematic coordination of the arm. The elbow must move along a path that ensures the force is applied directly behind the shot put's centre of gravity; any slight deviation in the angle of the shoulder or elbow joint results in a loss of mechanical force (Hochman & Zasada, 2026; Saračević et al., 2018). Recent studies indicate that the angular velocity of the thrower's elbow is directly proportional to the distance achieved; the more complete and rapid the extension at the right moment, the greater the acceleration gained by the shot put. Furthermore, the timing of the contraction of the throwing arm's muscles must be in harmony with the rotational or gliding movement (depending on the technique used). Students often struggle to maintain the 'linear path' of the throwing hand, which causes a dispersion of forces. Therefore, analysing kinematic variables such as (displacement, velocity, acceleration, and angles) of the arm allows us to develop ideal models that students can emulate (Jiao et al., 2025).

The significance of this research lies in its ability to bridge the gap between theoretical skill performance and precise mechanical application among university students, as it helps identify the biokinematic variables that most influence throwing distance to guide the teaching and training process, and provides specialists with accurate numerical data to help assess technical performance and correct common errors in arm movement, and to raise students' sporting achievement levels by relying on scientific principles rather than trial and error, thereby reducing the effort and time required in the educational process.

As for the research problem, the researcher's observation of the practical reality among students at the Faculty of Physical Education revealed a clear disparity in numerical levels (distance achieved) in shot put performance, despite the students' similar physical builds. The researcher believes that this weakness may be attributed to a lack of precise understanding of the biokinematic variables governing arm movement during the push-off and take-off phases, as many students focus on arm muscle strength without considering the correct mechanical angles or the required linear velocity, leading to a significant loss of the force exerted. The research question was therefore formulated as follows: "What is the nature of the relationship between the biokinematic variables of arm movement during the push phase and numerical performance (throwing distance) among students?"

Research objectives

1. To identify the values of certain biokinematic variables affecting the push-off in the research sample.
2. To identify the correlation between these variables and the achieved throwing distance.

Research Hypotheses

1. There is a statistically significant correlation between certain biokinematic variables (take-off speed, take-off angle and take-off height) and throwing distance among college students.

Research Scope

1. Human field: Fourth-year students at the Faculty of Physical Education and Sports Sciences – University of Samarra. 2025–2026.
2. Temporal scope: 19 February 2026 to 5 April 2026

3. Spatial scope: Samarra Stadium

METHODS

Research Methodology: A descriptive-analytical approach using a correlational design was employed due to its suitability and the nature of the research problem.

Research Population and Sample: The research population was purposively selected from fourth-year students at the Faculty of Physical Education and Sports Sciences, Samarra University, for the academic year (2025–2026). The sample comprised 12 students, of whom 4 were excluded for the purposes of the exploratory study. To identify the sample characteristics, the researcher calculated the mean, standard deviation and skewness coefficient for certain sample characteristics to ensure the main study and its results were highly accurate, for the variables (height, age and weight). Table (1) shows the characteristics of the sample members for these variables.

Table 1. Shows the characteristics of the sample

No	Statistical parameters Variables	Unit of measurement	Arithmetic mean	Standard deviation	Skewness
1	Lifespan	Year	22.55	1.39	0.24-
2	Mass	kg	67.1	1.647	0.97-
3	Length	cm	1.74	0.122	0.57

Equipment, tools and methods used in the research:

Data collection methods

The researcher used the following tools to collect data relevant to the research, including:

1. Face-to-face interviews.
2. Arabic and foreign sources.
3. Tests and measurements.
4. Observation.
5. The internet.

Tools and equipment used in the research

The researcher used a number of tools and devices to assist with the research, including:

1. Weights of 4 kg (4 in total).
2. Two measuring tapes.
3. A German-made precision electronic scale.
4. One camera phone (iPhone).
5. A computer.
6. Camera tripod (1).
7. A notebook.
8. Whistle.
9. Drawing set.
10. Chalk.

Skill test for shot put:

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Purpose of the test: To measure the horizontal distance of the shot put.

Test description:

The thrower propels the shot from the full circle within the throwing circle; the distance is measured from the inner edge of the circle towards the throwing sector to the nearest mark left by the shot during its descent, from the moment the shot leaves the hand at the end of the push phase to the furthest horizontal distance to the ground, measured vertically outside the throwing circle (m/cm) Each member of the sample is allowed six attempts, and the best three attempts are recorded in accordance with international rules. An attempt is considered a foul if the implement lands outside the throwing sector or if the thrower touches or crosses the stop board.

Kinematic variables:

The most important kinematic variables affecting performance were identified after consulting scientific sources in biomechanics, as well as scientific sources in athletics (projectile launch speed, projectile launch angle, projectile launch height).

Angle of release: This is the angle formed between the horizontal line passing through the centre of mass and parallel to the ground before the projectile is released from the athlete's hand, and the trajectory of the projectile's centre of mass in the air, measured in degrees.



Figure 1. Illustrates the angle of release

Projectile launch speed: This is calculated by dividing the launch distance (measured from the moment the projectile leaves the hand to 5 frames after launch) by the launch time, and is measured in metres per second.

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Figure 2. Shows the initial velocity of the weight

Height of the ball's launch point: the vertical distance between the ball's highest point before launch and the ground, measured in metres.



Figure 3. Shows the height of the weight's launch point

Preliminary experiment:

The researcher conducted the exploratory experiment on 24 March 2026, which fell on a Tuesday at 9 am, on a sample of two students from the same research community. The experiment involved conducting the test with the assistance of the support team (Appendix 1). The aim of this experiment was to identify: -

1. The time taken to complete the tests.
2. Ensuring the validity of the tools used in the field experiment.
3. Determining the appropriate number of assistants required to conduct the test.
4. Determining the locations, height and distance of the video cameras.

Field experiment:

The researcher conducted the field experiment on 31 March 2026 at the Samarra Stadium, where the research sample (8 students) underwent video recording of their

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technical performance in the shot put event over the course of a single day. Each thrower was given six attempts (in accordance with international rules), after which the three best throws by each thrower were selected for analysis using the Kinovea motion analysis software.

Video recording:

The camera was positioned to the right of the athlete, 45. m from the centre of the throwing circle and mounted on a tripod with the lens 1.20 m above the ground. Filming was carried out at a speed of 60 frames per second at a right angle to the athlete, ensuring that all technical phases of the shot put event were captured. A measuring tape (1 m) was used.

Statistical methods:

After collecting the data, the researcher analysed it statistically using the SPSS statistical package. The statistical measures used were the arithmetic mean, standard deviation, Pearson's simple correlation coefficient, and the skewness coefficient.

RESEARCH RESULTS

Presentation of the results for the arithmetic means, standard deviations and skewness coefficients

Table 2. Shows the results of the arithmetic means, standard deviations and skewness coefficients.

No	Variables	Minimum value	Maximum value	Arithmetic mean	Standard deviation	Skewness
1	Achievement	5.4 m	9.8 m	8.02 m	0.201	0.21-
2	Launch speed	4.20	5.69	5.02	3.35	0.810
3	Centre of gravity height above the ground at launch	174 cm	196 cm	189.66 cm	14.9	0.41
4	Centre of gravity angle	27	49	36.25	7.66	0.98

Initial velocity of the weight: From the results in Table (2), we can see that the arithmetic mean of the initial velocity of the weight is (5.02) with a standard deviation of (3.35), whilst the coefficient of variation is (0.810).

Height of the weight above the ground at the moment of launch: From the results in Table (2), we see that the arithmetic mean of the height of the weight above the ground at the moment of launch is (189.66 cm) with a standard deviation of (14.9), whilst the skewness coefficient is (0.41).

Angle of launch: From the results in Table 2, we see that the arithmetic mean of the angle of launch is 36.25 degrees with a standard deviation of 7.66, whilst the coefficient of variation is 0.98.

Presentation of correlation coefficient results for performance with biomechanical variables

Table 3. Shows the correlation coefficient results for biokinematic variables with performance

No	Variables	Correlation coefficient	Significance level	Type of significance
1	Acceleration	0.958	0.00	Moral
2	Lift-off weight	0.313	0.04	Mean
3	Angle of launch	0.852	0.03	Mean

This table presents the results of correlation analysis of three variables. Acceleration has the highest correlation coefficient of 0.958 with a significance level of 0.00 and is classified as moral significance, indicating a very strong relationship. The launch angle is in second place with a correlation coefficient of 0.852 and a significance level of 0.03, classified as average significance. Meanwhile, the weight at take-off had the lowest correlation coefficient of 0.313 with a significance level of 0.04, also classified as an average significance, indicating a weaker relationship than the other two variables.

DISCUSSION

Discussion of the correlation between the launch angle variable and performance.

Table (3) shows that there is a statistically significant correlation between the launch angle variable and performance. This is due to the significant influence of the launch angle on projectiles, as it is one of the factors determining horizontal distance; the motion of a projectile is governed by specific mechanical laws and systems, and one of the most important of these factors is the launch angle. It is worth noting that this achieved angle falls within the ideal range for the launch of projectiles in general, as in all throwing events—such as discus, javelin and shot put—the highest point of the projectile is higher than its landing point; consequently, the launch angle here will be less than 45° to achieve the appropriate flight distance, as the launch angle for good throwers ranges between $35\text{--}40^\circ$. The research results showed that the arithmetic mean of the launch angle was 36° , which means it falls within the specified range for throwing.

Discussion of the correlation between the variable of the height of the weight above the ground at the moment of throw and performance.

It is evident from Table (3) that there is a significant correlation between the variable of the height of the weight above the ground at the moment of throw and performance. The researcher believes that the height of the implement above the ground gains its importance and contributes to performance through the full extension and kinetic transfer occurring in all the body's joints, starting from the foot joints, passing through all the body's joints and angles, and ending at the wrist joint, as this extension and transfer gives the implement additional kinetic momentum.

Discussion of the correlation between the variables of starting speed and performance

Table (3) shows a significant correlation between the variables of initial velocity and performance. The researcher attributes this to the fact that the greater the initial velocity, the greater the distance travelled by the weight during flight. This was confirmed by Qasim Hassan Hussein and Iman Shaker Mahmoud, who stated "Given that launch speed is related to the rate of force exerted and passing through the centre of gravity of the object, the greater the total force exerted, the greater the distance travelled by the object; that is, the force exerted in a shorter time leads to an increase in

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the force characterised by speed, which is subject to Newton's laws of acceleration, as acceleration has a direct relationship with speed".

CONCLUSIONS AND RECOMMENDATIONS

Based on the results, analysis and discussion presented above, the researcher has reached the following conclusion:

There is a significant correlation between the angle of take-off, take-off speed and take-off height, and performance.

The researcher made a set of recommendations, as follows:

1. The need to emphasise the importance of conducting such studies and other field and track and field events.
2. Such studies should be conducted at different levels, such as among young people or older participants.
3. The need to take these mechanical variables into account, given their clear impact on performance.

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