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ORIGINAL STUDY

Analysis of the Relationship Between the Timing of Foot Pressure Mechanics and Force at the Moment of Leaping and the Accuracy of Heading of Young Football Players

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Abstract

Football is a dynamic sport that requires both physical and technical skill because it is played within a specific timeframe and in a large space; physical ability is inseparable from technical proficiency among a match. This research aims to analyze the relationship between the timing of foot pressure, force generated at take-off, and heading accuracy in youth football players. A descriptive correlational approach was used on a sample of (8) players. Data were collected using a Foot Scan platform andvideo analysis. The results it was significant correlations between biomechanical variables and heading accuracy. The highest recorded correlation reached (R = 0.845) between instantaneous propulsive force and heading accuracy, indicating the critical role of rapid force production. Additionally, the elevation of the center of mass during take-off showed a strong correlation (R = 0.826), highlighting the importance of vertical force application. The findings confirm that optimal heading performance depends on the integration of explosive power, precise timing, and balanced plantar pressure distribution. The research concluded that improving heading accuracy requires generating high force in a short time while maintaining dynamic balance during take-off.

Keywords: Foot pressure timing, Explosive power, Heading accuracy, Biomechanics, football

1. Introduction

Football is a dynamic sport that requires both physical and technical skill because it is played within a specific timeframe and in a large space; physical ability is inseparable from technical proficiency during a match. Physical abilities cannot be separated from technical performance during competition. Among the essential skills in football, heading from a jumping position is considered one of the most difficult and critical skills, as it requires precise neuromuscular coordination starting from ground contact and continuing until the moment of ball contact and direction toward the goal.

This skill need the player to sufficient explosive power from the lower limbs to achieve appropriate vertical elevation, and the ability to control body position and accurately direct movement toward the ball. as well as Research in sports biomechanics that the efficiency of such movements depends largely on the interaction between force magnitude and the rate of force development, as well as coordination between different body segments during the take-off and flight phases (Suchomel et al., 2018; Cormie et al., 2011).

Ground reaction force and plantar pressure distribution play a crucial role in determining the quality of movement execution. Balanced pressure between the feet contributes to maintaining dynamic stability and

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reducing unnecessary lateral deviations, which accuracy in skill performance (Queen et al., 2020; Bishop et al., 2021).

Advanced and reliable tools for analyzing athletic performance have now emerged. performance, such as the Foot Scan system, which enables accurate measurement of plantar pressure distribution, timing, and force variables in real time. This represents a significant improvement over traditional observational methods. Kinematic analysis software can provide the required data to correct performance errors or enhance existing strengths (Al-Zuwaini et al., 2024).

The timing of force application during the take-off phase is a key factor influencing performance efficiency. A shorter ground contact time combined with high force production enhances the utilization of the stretch-shortening cycle, leading to improved explosive performance and; movement coordination (Komi, 2003; Markovic & Mikulic, 2010).

The importance of these variables, there is still understanding the regarding relationship between foot pressure timing, force production at take-off, and heading accuracy in youth football players. many young players possess acceptable levels of physical fitness, their performance in heading from a jump often remains below the required level. This may be attributed to diffrent in pressure timing, inefficient force utilization during take-off, or asymmetry in pressure distribution between the feet.

Therefore, investigating these relationships is essential for providing accurate scientific data that can assist coaches in improving player performance, particularly in difficult skills such as heading. The present research is significant as it focuses on the temporal characteristics of foot pressure using the Foot Scan system, shifting performance evaluation from subjective observation to precise quantitative analysis. This approach offers an objective solution for distributing pressure as a crucial factor linking muscular strength and technical performance, especially among young players who are the foundation for reaching higher competitive levels..

This research aims to identify the timing characteristics of foot pressure mechanics and the magnitude of force at the moment of take-off in youth football players using the Foot Scan platform. It also seeks to determine heading accuracy during jumping and to examine the relationships between biomechanical variables, including pressure, force, timing, and heading accuracy.

The research hypothesizes that there are no statistically significant correlations between: (1) foot pressure timing and heading accuracy, (2) force generated at take-off and heading accuracy, and (3) the combined effect of timing and force and heading accuracy.

The research population consists of youth football players from Air Force Club during the 2024/2025 season. The temporal scope of the study extends from 25/6/2025 to 20/8/2025, and the spatial scope is limited to the Air Force Club stadiums in Baghdad

2. Methodology and procedures

The population of the study was selected vertically from (15) young players from Air Force Club who can perform the skill well. Goal keepers were excluded. The sample consisted of (8) players, who represented 53.33% of the population as shown in Table 1:

Table 1. The statistical indicators of the arithmetic mean and coefficient of variation.

Statistical indicators					
coefficient of variation	±Y	X	unit of measurement	Sample specifications	No
8.41%	1.37	18.30	Year	Age	1
2.03%	3.39	177.30	Cm	Total height	
4.53%	2.85	63	Kg	Mass	2
18.21%	2.88	5.50	Year	Training age	3
8.13%	7.42	99.33	Cm	Leg length	

Table 1 showed that the sample is homogeneous because the coefficient of variation is less than 30%.

The researchers used Arabic and foreign sources, the internet, individual interviews, questionnaires, data entry forms, an HP computer, CDs, a foot scanner (Foot Scan platform) with accessories (1), a measuring tape, a video camera (240 frames per second) with a tripod, the Kinovea motion analysis software, and 5cm wide adhesive tape for marking research variables. A number of tests were selected, including the explosive power test of the legs (vertical jump from a standing position) and the accuracy test of heading the ball (from inside the penalty area).

3. Procedures

3.1. Field procedures

3.1.1. Tests

1st test: Explosive power test for feet (Al-Fadhli & Alwan, 2007: 210)

Name of test: Explosive power test for feet

Tools: Football field foot scanner (f00t Scan), high-speed video camera (240 bps) with tripod (Stand), electronic calculator.

Performance: From the approach stage, the player takes a one-step jump onto the footscan platform in front of us, high and vertical with both feet, and performs the heading while jumping. The player aims to

perform the highest possible vertical height and cover the greatest vertical distance when jumping.

Scoring: the testee tries twice and the best try is counted. The player's mass, the vertical distance achieved from the jump onto the power platform, and the propulsion time are used to measure the explosive power of the legs. The movement is then analyzed using Kinovea software to measure the propulsion time from the moment the movement begins to the moment of landing. The distance achieved is recorded in meters and fractions of meters, and the explosive power is calculated by using the following law: (Al-Fadhli & Alwan, 2007: 230)

$$\frac{2\,(\text{distance}) \times \text{Atheletic mass}}{3\,(\text{time})} = \text{The explosive power of the legs}$$

Mass = player's mass, time = time of performance from the moment of take off to the moment of landing, and distance = the vertical distance traveled by the player from the moment he leaves the platform until the moment of landing.

Unit of measurement: The unit of measurement specified for the above-mentioned relationship is (watt).

2nd test: Heading accuracy test (from inside the penalty area): (Hassanein, 2004: 293).

Name of test: Heading accuracy test (from inside the penalty area).

Goal of the test: to measure the accuracy of heading skills of football players.

Tools: Football field, balls, ball launcher (or passing teammate), test equipment (goals divided into numbered circles or circular openings), foot scanner (foot Scan), high-speed video camera (240 rpm) with tripod, electronic calculator.

3.2. Performance

The test is performed when the player performing the test begins jogging from the start of the 18-yard line towards the 6-yard area. The ball is thrown to the player using a ball-launching device. The player then heads the ball while moving, aiming it into one of the circular openings in the test device (the board attached to the goal). Each player has three attempts from the forward movement, as shown in Fig. 1 below.

3.3. Scoring

Successful try: when the ball passes the numbered circular opening. Points are calculated based on the number written on the opening. The points are then added together.

Failed try: when the ball fails to pass the openings. The motion is analyzed using the Kinovea software to measure the variables which are: 1 - Foot strike force at the moment of takeoff 2 - Instantaneous propulsive force at the moment of takeoff 3 - Time of support at the moment of propulsion 4 - Lateral variance 5 - Strength of the left leg 6 - Strength of the right leg 7 - Maximum pressure.

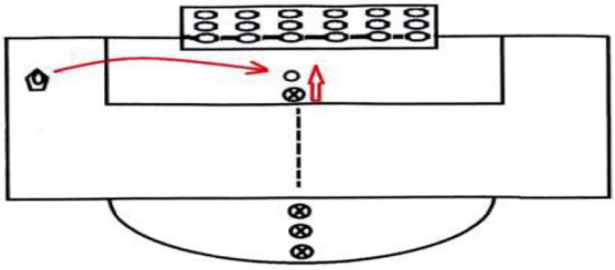

Fig. 1. The accuracy test of heading the ball from inside the penalty area.

3.4. Pilot study

The pilot study was conducted on (2) players from the research population and outside the main experiment at 4:00 pm on Thursday, 3/7/2025 at the Air Force Club to check the function of the tools and devices used in the tests and to Ensure the functionality of the video cameras, determining the final camera positions, and fixing their dimensions so that they provide clear images of the players while performing the skill.

3.5. Biomechanical variables related to skill and how it is measured

- The instantaneous thrust of the legs was measured using a foot scanner.
- The biomechanical variables were measured by filming the skill in question and analyzing it using Kenova.

The resulted variables are 1 - Foot strike force at the moment of takeoff 2 - Instantaneous propulsive force at the moment of takeoff 3 - Time of support at the moment of propulsion 4 - Lateral variance 5 - Strength of the left leg 6 - Strength of the right leg 7 - Maximum pressure.

3.6. Main experience

The researchers conducted the video recording on Sunday, July 16, 2025, at 4:00 PM in the outdoor field of the Air Force Club. The researchers used two

cameras. The cameras were placed on a tripod and fixed at a height of 1.65 meters from the camera lens focal point to the ground, and at a distance of 10.80 meters from the center of the movement and from the force measurement platform. One of the cameras was front-facing and the other side-facing, allowing the player to be filmed from the moment of approach to the landing after jumping high. Video footage is taken simultaneously of the player performing the heading accuracy test from inside the penalty area. Thus, the skill and the variables are visualized. The researchers then analyzed the skill using Kenova software.

3.7. Statistical processes

The SPSS statistical software package was used to statistically process the results.

4. Results

5. Discussion of the results

The results shown in Table 2 reveals a noticeable difference in the values of biomechanical and physical variables of the sample. The average explosive power of the two legs was (1.84 m), an indicator that reveals good muscle mass enabling the players to perform vertical jumps at a level suitable for the requirements of heading from a jump, which needs continuous and repeated practice to improve both physical fitness and technical performance. Al-Mukhtar (1998) believes that repeating the exercise multiple times in different positions sustains the skill; which indicates that this high value helps players take a longer take off time, giving them time to adapt to the ball's trajectory before heading it away from the goalkeeper. Research in the field of football biomechanics confirms that athletes with stronger lower limb musculature demonstrate superior capacity to

Table 2. The arithmetic means, standard deviations, and correlation coefficient for the variables.

Significance	Significance level (Sig)	Calculated R R value	standard deviation	Mean	unit of measurement	Variables
Significant	0.001	0.812	0.049	1.84	Meter	The explosive power of the legs
Significant	0.000	0.845	11.425	4462.60	Newton	The strength of the foot strike at the moment of takeoff
Significant	0.002	0.778	29.74	1359.59	Newton	Instantaneous thrust at the moment of takeoff
Significant	0.003	−0.731	0.061	0.547	Second	Pivot time at the moment of thrust
Significant	0.000	0.826	0.078	1.56	Meter	Elevation of the body's center of mass during takeoff
Significant	0.004	−0.689	18.62	312.45	Newton	Lateral variation in pressure distribution
Significant	0.003	0.702	95.40	2210.30	Newton	Strength of the left leg
Significant	0.002	0.715	102.15	2252.30	Newton	Strength of the right leg
Significant	0.001	0.768	6.35	58.70	Newton/cm^2	Maximum applied pressure

Fig. 2. Heat map of plantar pressure distribution on the left and right feet during takeoff — red areas indicate the highest pressure concentration on the ball.

Fig. 3. The arithmetic means with the correlation coefficients (r) — blue represents the positive correlation, red represents the negative correlation.

execute explosive jumping and thrust movements, as the ability to generate rapid ground reaction force is closely linked to the neuromuscular efficiency of the leg extensors (Fahey et al., 2025; Wong et al., 2020). In terms of ground pressure, the force of the foot strike at the moment of takeoff was (4462.60 Newtons), which expresses the players' ability to utilize body weight and momentum to generate a high ground reaction force. The players who achieved higher accuracy did not rely on absolute power as much as they relied on the rate of power development in a short time with a pivot of (0.547 seconds). This is consistent with what Cormie et al. (2011:18) stated, that maximum muscle power depends on neuromuscular coordination in the first moments of contraction. On the other hand, the instantaneous thrust was (1359.59 Newtons), which indicates acceptable efficiency in converting muscular effort into rapid thrust in a short time. Researchers explain that instantaneous thrust and anchorage time work together; producing high force in a short contact period and giving the players a quick and balanced launch that prepares the body to take off in the aimed direction. Regarding the pivot time, it was (0.547 seconds), which reveals another aspect of performance. A shorter contact period with the ground generally carries a positive connotation, indicating a better ability to generate thrust that aids the football player's performance. Researchers believe that the key is not the total amount of strength, but rather the rate at which the player develops instantaneous strength. This is what the researchers (Cormie et al., 2011) confirmed: that the shorter the time of rest, the greater the player's ability to utilize the "lengthening and shortening cycle" to convert potential energy into vertical speed.

In the same context, the height of the body mass during takeoff was (1.56 m), indicating that the players have the minimum altitude capability required to perform the skill well. The value of the maximum applied pressure is a measure of the direction of force. High and consistent pressure helps to adjust the vertical direction of movement, which improves the angle of the body's thrust and increases the height of the body's center of mass, thus preparing players for a more accurate heading.

The pressure data shows that the lateral variation in pressure distribution was (312.45 Newtons). This score indicates that neither foot contributes to producing the force. However, a comparison between the strength of the right leg (2252.30 Newtons) and the left one (2210.30 Newtons) shows a relative similarity that refers to a suitable muscular balance between the two legs. The lateral variance variable is affected in the pressure distribution. Although the difference in results is small, its kinematic effect on the jump direction is always present. Thus, it becomes clear that the convergence of the two legs' strengths represents a key variable for kinetic stability during takeoff. The researchers believe that the lateral variation in pressure distribution provides an explanation for the decline in accuracy among some members of the sample, which may lie in the imbalance of force distribution between the right foot (2252.30 N) and the left foot (2210.30 N), leading to a deviation in the path of the body's center of mass during flight (1.56 m). Komi (2003, p. 190) said that imbalance in the thrust phase leads to a loss of "directed kinetic momentum," making the timing of heading the ball inaccurate as the body is preoccupied with restoring its balance in the air.

In terms of maximum applied pressure, it scored (58.70 N/cm^2), which is an indicator of the concentration of force in a limited area of the foot surface during thrust. Concerning skills, the average accuracy of heading was (7.25 degrees), which refers to a good result. Researchers believe that the high concentration of pressure in a limited space reflects the quality of the base of support. High and regular pressure helps to control the vertical direction of the player's movement when performing the skill of heading with a jump. Lees et al. (2010, p. 810) confirmed that the biomechanical properties at the moment of contact with the ground determine the kinematic path of the body in the next stage (take off), which explains the significant correlation between pressure indicators and aiming accuracy. Therefore, the researchers concluded that optimal performance in the skill of heading is not in absolute power alone, but requires the availability of three conditions: producing high power in a short time and distributing it in a balanced way between the right and left legs. Lack of any of these three elements leads to a deficiency in heading, even with a high muscular strength. Thus, the researchers stresses that the decline in shooting accuracy in the sample is due to three main reasons, namely the lack of performance in terms of the required integration between the size of the force and the timing of its control, lateral variation in pressure distribution which affects the stability of the rise base, and the need to develop and regulate the timing of the thrust phase more accurately.

6. Conclusions

- The results showed a strong correlation between the explosive power of the legs and instantaneous propulsion indicators, confirming the hypothesis that improved muscular speed is a crucial prerequisite for enhancing the efficiency of heading.
- The instantaneous propulsion variables—propulsion force and anchorage time—have a clear impact on the player's performance. In other words, the ground contact phase is the true juncture where the overall quality of the skill's execution is determined.
- Balance in the distribution of pressure between the feet enhances the stability of the base of support and reduces lateral body deviations, which directly impacts the accuracy of heading from a jump.
- Achieving accuracy in heading is not limited to possessing muscular strength, but requires functional integration between explosive power, timing, pressure distribution, and biomechanical variables combined.

7. Recommendation

The researchers recommend the following:

- Directing the training process towards reducing the time spent in the center and accelerating the rate of instantaneous power production, due to its direct impact on improving efficiency when shooting with a jump.
- Employing ground pressure analysis techniques such as Foot Scan devices in the kinematic evaluation of players, due to the accurate quantitative readings they provide that help in diagnosing and correcting hidden mechanical errors.
- Educating coaches on the importance of paying attention to the timing of the thrust, in addition to the magnitude of the force produced, because this variable has proven to have a decisive impact on the accuracy of skill performance.
- Designing exercises aimed at achieving balance in the distribution of pressure between the feet, in order to increase motor stability before takeoff and reduce the risk of deviation when jumping.

Author's declaration

Conflicts of interest

None.

We confirm that all tables and figures in this article are the original work of the researchers.

Ethical clearance

This manuscript was approved by the Scientific Committee of the College of Physical Education and Sports Sciences for Women / University of Baghdad, on (2025/02/10).

Authors' contributions

All contributions to this study were carried out by the researchers: Widad Kadhim Majeed, Huda Shihab Jari, Mariam Abduljabbar Khudhair, and Félix Arbinaga Ibarzábal. They participated in implementing the study procedures, collecting and organizing data, contributing to the implementation of the experimental program, and drafting the manuscript. They also contributed to developing the research idea, designing the study, supervising the research procedures, interpreting the results, and reviewing and finalizing the manuscript, with the assistance of experts in statistics and translation.

Facilitating the task

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Roles of each researcher in the study

- First researcher: Widad Kadhim Majeed was responsible for participating in the implementation of the study procedures, collecting and organizing the data, assisting in conducting the experimental program, contributing to the interpretation of the results, and assisting in drafting the manuscript.
- Second researcher: Huda Shihab Jari was responsible for conceptualizing the research idea, designing the study, reviewing the literature, supervising data collection and experimental procedures, interpreting the results, and reviewing the manuscript.
- Third researcher: Mariam Abduljabbar Khudhair was responsible for contributing to the implementation of the experimental program, organizing the data, participating in the analysis, and assisting in writing the manuscript.
- Fourth researcher: Félix Arbinaga Ibarzábal was responsible for general scientific supervision, contributing to the interpretation of the results, reviewing the manuscript, and performing the final revision.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Research translation

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تحليل العلاقة بين توقيت ميكانيكية ضغط القدم والقوة في لحظة الارتقاء ودقة الضرب بالرأس لدى لاعبي كرة القدم الشباب

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الخلاصة

تُعد كرة القدم من الألعاب الديناميكية التي تتطلب مهارات بدنية وفنية في الوقت نفسه، لأنها تُمارس ضمن إطار زمني محدد وفي مساحة واسعة، مما يجعل القدرة البدنية مرتبطة ارتباطًا وثيقًا بالكفاءة الفنية أثناء المباراة. يهدف هذا البحث إلى تحليل العلاقة بين توقيت ضغط القدم، والقوة المتولدة عند الارتقاء، ودقة الضرب بالرأس لدى لاعبي كرة القدم الشباب. استخدم الباحثون المنهج الوصفي الارتباطي على عينة مكوّنة من (8) لاعبين. وتم جمع البيانات باستخدام منصة فحص القدم (Foot Scan) وتحليل الفيديو. أظهرت النتائج وجود علاقات ارتباط معنوية بين المتغيرات البيوميكانيكية ودقة الضرب بالرأس، حيث بلغ أعلى معامل ارتباط مسجل ($R = 0.845$) بين القوة الدافعة اللحظية ودقة الضرب بالرأس، مما يشير إلى الدور الحاسم للإنتاج السريع للقوة. كما أظهر ارتفاع مركز الكتلة أثناء الارتقاء ارتباطًا قويًا ($R = 0.826$)، مما يبرز أهمية تطبيق القوة العمودية. وأكدت النتائج أن الأداء الأمثل للضرب بالرأس يعتمد على تكامل القوة الانفجارية، والتوقيت الدقيق، والتوزيع المتوازن لضغط باطن القدم. وخلص البحث إلى أن تحسين دقة الضرب بالرأس يتطلب توليد قوة عالية خلال زمن قصير مع الحفاظ على التوازن الديناميكي أثناء الارتقاء.

الكلمات المفتاحية: توقيت ضغط القدم، القوة الانفجارية، دقة الضرب بالرأس، البيوميكانيك، كرة القدم.