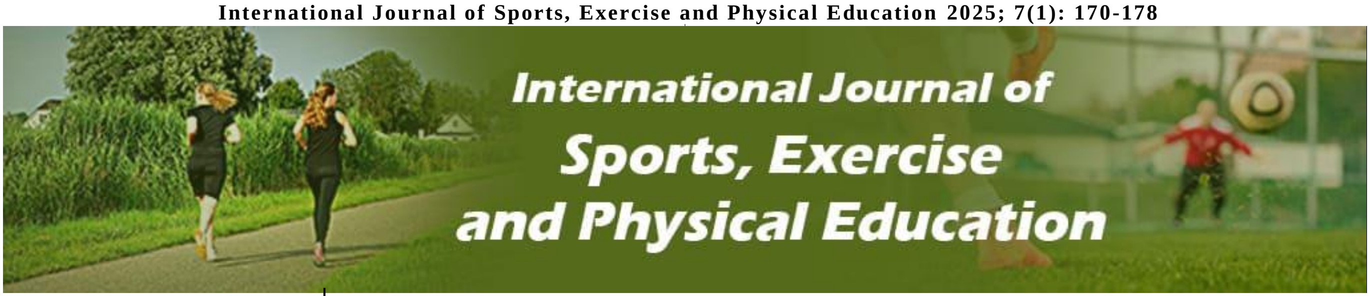
International Journal of Sports, Exercise and Physical Education 2025; 7(1): 170-178



ISSN Print: 2664-7281
ISSN Online: 2664-729X
Impact Factor: RJIF 8
IJSEPE 2025; 7(1): 170-178
https://www.sportsjournals.net
Received: 09-02-2025
Accepted: 12-03-2025

Sarmad Qais Naji
Assistant Lecturer, Faculty of Physical Education and Sports Sciences, University of Babylon, Iraq

Dr. Ali Jawad Abed
Professor, Faculty of Physical Education and Sports Sciences, University of Babylon, Iraq

Corresponding Author:
Sarmad Qais Naji
Assistant Lecturer, Faculty of Physical Education and Sports Sciences, University of Babylon, Iraq

Comparison of the biomechanical variables of the straight forward aerial jump skill with 2 turns on the floor exercise mat for the Iraqi and Iranian national team players

Sarmad Qais Naji and Dr. Ali Jawad Abed

DOI: https://www.doi.org/10.33545/26647281.2025.v7.i1c.170

Abstract
The 2-turn straight aerial jump is an advanced and complex kinetic skill in artistic gymnastics, requiring a high degree of integration between physical and skill capabilities. This skill requires precise coordination of biomechanical variables, such as propulsion force, joint angles, angular velocity, center of mass, and flight time. These factors significantly influence the quality of technical performance. Therefore, analyzing these variables is essential, as it helps identify players' strengths and weaknesses, contributing to improved technical performance and raising the level of excellence in international competitions. The research aims to identify the biomechanical variables related to the performance of the straight aerial jump skill with 2 turns on the floor exercise mat, diagnose errors in the performance of the straight aerial jump skill with 2 turns and the values of the time-force curve and some biomechanical indicators, identify the specific strength and force moments of the research sample in the performance of the straight aerial jump skill with 2 turns on the floor exercise mat. Therefore, the researchers decided to analyze the biomechanical variables that affect the technical performance of the straight aerial jump skill with 2 turns, with the aim of identifying the technical errors resulting from a defect in these variables and the impact of this on the classification of players in international championships. The researchers pointed out the importance of studying these variables to address shortcomings in technical performance and improve the level of players in international competitions. The researchers assumed the existence of significant differences in the biomechanical variables (such as joint angles, speed of performance, center of mass) between the performance of the straight aerial jump skill with 2 turns on the floor exercise mat between the players of the Iraqi and Iranian national teams. "Kinematic and kinetic factors (such as time, the researchers used the descriptive approach with the survey method to solve the research problem, in line with the nature of the research objectives and its practical solutions. This approach provides an opportunity to analyze the current reality of sports performance and evaluate it scientifically, which helps in deriving important conclusions that contribute to the development of sports performance. The research community and sample included the players of the Iraqi national team for advanced artistic gymnastics, which includes (6) players, (1) Iranian player who were selected vertically based on the classification of the Iraqi and Arab Gymnastics Federation. The researchers concluded that the results showed clear differences in the performance of the straight air jump skill with two turns between the players of the Iraqi and Iranian teams, especially in the propulsion force and joint angles, which affects the quality of performance. Technical errors and differences in special strength were also identified. The researchers recommend implementing training programs based on biomechanical analysis to improve performance, using advanced analysis techniques to accurately evaluate performance, and correcting joint errors and flight time to increase efficiency.

Keywords: Aerobic jump, biomechanical analysis, technical performance.

Introduction

Artistic gymnastics is a sport that requires high coordination between physical abilities and complex kinetic skills. It involves numerous devices that require precise performance. Motion analysis plays a fundamental role in improving skill performance by accurately evaluating movements and identifying technical errors in the motion path. Using the ideal motion model in learning and training processes is an effective method for correcting errors, helping to improve the motion path for performing advanced skills, such as the straight aerial

Jump with two turns. (Abdullah, 2014) [1], (Ziad, Fawaz Salem Al-Radisat, Muhammad, Darwish AL-Kurdi, & Ziad, 2022) [14]. This skill requires precise balance, explosive power, and angular velocity, making it a challenging skill that requires a high focus on biomechanical variables such as propulsion, joint angles, and flight time. Biomechanical analysis helps identify and correct performance deficiencies, enhancing the quality of execution and reducing technical errors. (Winter DA, 2009) [13]. (Mkaouer B, *et al*., 2020) [10]. Technological advances in motion analysis tools have facilitated the process of evaluating technical performance, especially in complex skills, and have opened the way for the development of advanced training programs based on accurate scientific analysis. The straight aerial jump with two turns is considered one of the skills in which the importance of biomechanical evaluation is highlighted, as improving the strength and fluidity of the movement is directly related to the efficiency of athletic performance. The research problem was evident in analyzing the technical performance level of the straight aerial jump with two turns on the floor exercise mat. The researcher noticed through his field experience and tournaments that the players' performance in this skill is weak compared to Arab and foreign teams, which leads to lower evaluation scores. The problem lies in the presence of technical errors that affect the technique and, consequently, the result. The research seeks to use biomechanical analysis to identify the variables affecting the improvement of technical performance and the adjustment of technique according to international standards, with the aim of improving the level of achievement and raising scores in competitions. The research objectives are to identify the biomechanical variables specific to the performance of the skilled on the floor exercise mat, diagnose errors in the performance of the skill, the values of the force-time curve, and some bio-kinematic indicators, and identify the specific strength, force moments, and force moments of the research sample on the floor exercise mat. The researchers hypothesized the existence of statistically significant differences in the force-time curves for the selected research skill, and the existence of statistically significant differences between them depending on the degree of difficulty of the skill in the bio-kinematic variables of the research skills and according to the degree of difficulty of performance. The research areas were: a group of (6) Iraqi national gymnastics players, (1) Iranian player, for the period from 12/1/2024 to 15/3/2024 in the sports hall at Ashur University College in Baghdad Governorate.

Methods and Procedures: The nature of the problem determines the research methodology in order to reach the truth and reveal it to arrive at a specific result. The researchers used the descriptive method using the survey method with its scientific steps, as it is appropriate for the nature of the research problem and its objectives, as it is the appropriate method for solving the research problem. The descriptive method clarifies the reality of incidents and reports their current facts through analysis and evaluation in order to derive important conclusions to correct this reality, update it, or create new knowledge that defines the research community as the advanced Iraqi national gymnastics team players, according to the classification of the Iraqi and Arab Gymnastics Federation, numbering (6) players, (1) Iranian player, chosen intentionally.

Tools used in the research: Arabic and foreign sources, the Internet, personal interviews, office tools, Tracker program, Kinovea, DYNA FOOT force sensor.

Research-specific tests

Power-time curve test: The player performs the straight front aerial flip with two turns after wearing the power-measuring bands and fluorescent markers. All connections are checked, and the Bluetooth on the computer is matched to the Bluetooth connected to the right and left bands. Signal strength is then verified. The player is then given the signal to begin performing the skill, synchronized with the support team to operate the cameras and begin video recording, each according to their position. After the skill is completed, all information for the power-time curve analysis is recorded in the computer program. The tester stores this data on the computer for later processing.

Exploratory Experiment: The researcher conducted the exploratory experiment on a player from the Iraqi national team for advanced men's artistic gymnastics on Saturday, February 1, 2024, at 4:00 PM, in the central indoor gymnastics hall of the sports halls complex (Martyr Samir Khamas Hall). The purpose was to assess the progress of the tests, adjust the components of the qualifying curriculum, and ensure the safety of the equipment and tools. Videography of the research sample: Videography is considered one of the best means of kinetic analysis to obtain information, as the analysis through its use is done to study the movement, its paths, and biomechanical changes, and then apply the mathematical and physical sciences to provide us with the final results. In order to identify the biomechanical variables that affect the performance of the skill, and in order to obtain a scientific formula to study the values of biomechanical variables, the researchers used videography, as videography is considered one of the important means of discovering errors and controlling the extent of convergence or divergence of the players' technical performance levels. From it, the researcher can, by drawing the paths of the body's points, describe and analyze the movement to determine the extent of convergence of the levels of a certain group of players. The geometric path of the body can also be determined by using the drawing scale. On this basis, the research sample was photographed using a Casio Exilim camera, where the photography was at a speed of (120 frames/second). The video camera was installed on a large tripod, and the height of the middle of the lens was (1.50 m) from the ground and at a distance of (6.45 m). The photography process took place in the closed hall for sports in Ashur University College, as shown. In Figure (1).

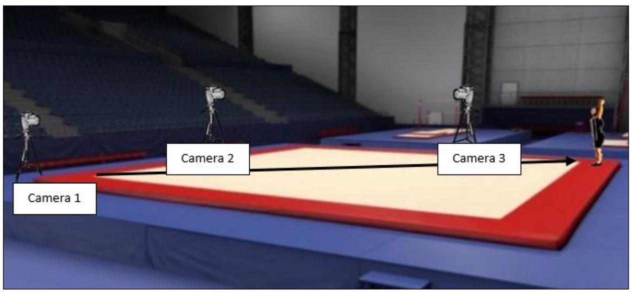


Fig 1: shows the locations of the cameras used to photograph the research sample

Dyna foot force sensor: A system for measuring the force variables applied to the ground during each running step. It consists of four parts: a data transmission base (a foot pedal placed in the shoe), a connection cable (which connects to the tester's leg), a signal receiver (which connects to a laptop and receives the signal from a distance of 20 meters for indoor halls and 10 meters for outdoor stadiums), and a Bluetooth device. The system operates after the step sensor is placed in the tester's shoe, the signal transmitter is attached to his leg, and data is entered, including the player's age, height, weight, and gender. The device measures the highest and lowest force variables, the areas of force distribution in the foot, acceleration, and other variables. See Figures 2 and 3.

Fig 2: Shows the Dynafoot device and its accessories.

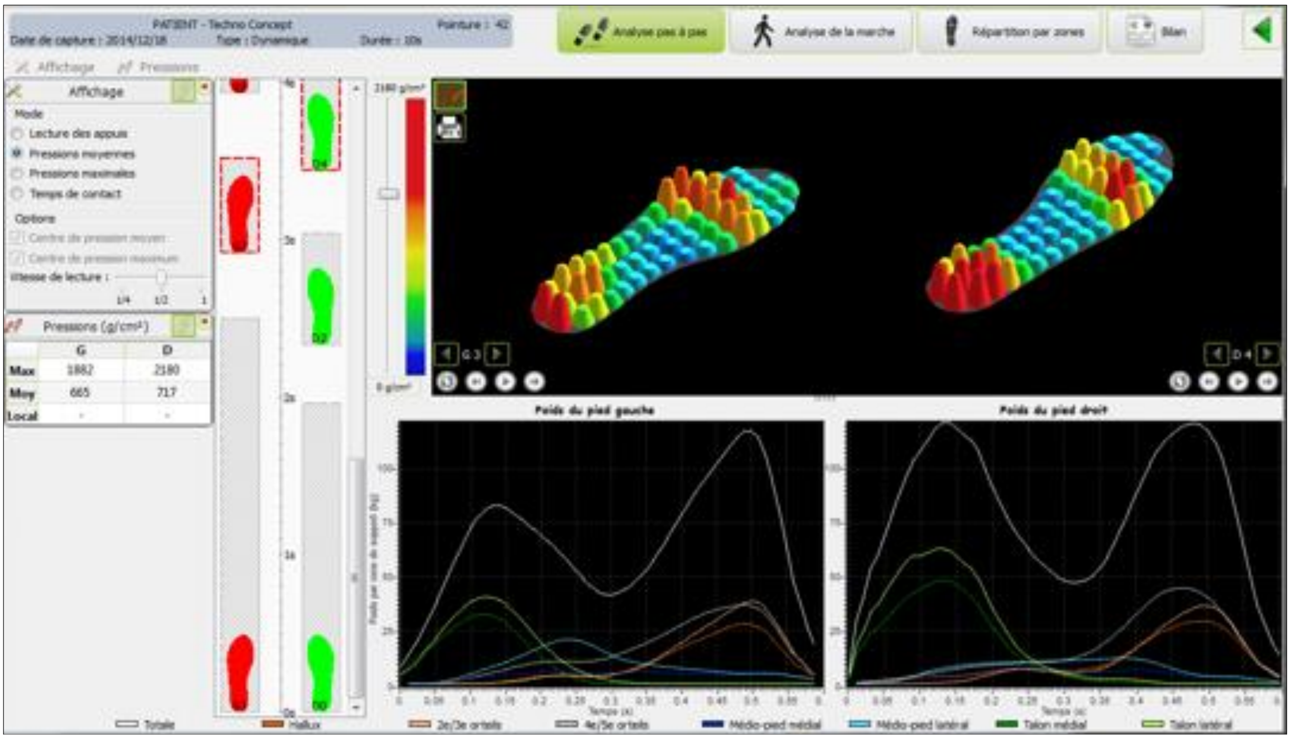


Fig 3: Shows the Dynafoot software

Biomechanical Analysis: Special computer programs were used to measure mechanical variables, including Tracker version 5.4 and Kinovea version 1.2. These programs were used to obtain the required variables. The computer analysis was conducted using the following steps:

1. The video footage was transferred from the camera to the computer as files and then to CDs to facilitate the analysis process.
2. The movement was segmented into a series of videos and images using Tracker to extract the specific variables (studied). These segments were stored as files in the computer's My Documents folder.
3. These files (segments) were then retrieved from the Tracker program installed on a ThinkPad computer, a program designed to analyze sports movements.
4. The angles were determined using Kinova analysis software.

Determining Biomechanical Variables

"The process of determining kinematic variables was carried out accurately and systematically using advanced motion analysis tools, which contributed to the extraction of reliable data for studying performance".

Velocity Variables

Peripheral Velocity: It is the speed at which any part of the body moves on a circular path around a specific axis of rotation. It is measured in meters/second and expresses the amount of distance that the body travels on the circumference of the circle during a unit of time. It is symbolized by the symbol and is calculated using the following relationship: v = r\cdot\omega as shown in the following figure:

Fig 4: Show how to measure the peripheral velocity of the lead leg (snatch velocity) in the preparatory phase.

Linear Velocity of the Center of Mass

The peripheral velocity of the center of mass is one of the basic kinematic variables that reflects the efficiency of a player's dynamic performance. It refers to the speed at which the center of mass moves along a linear path resulting from the rotational or translational motion of the body. It is the product of the angular velocity and the radius, which represents the distance between the axis of rotation and the center of mass.

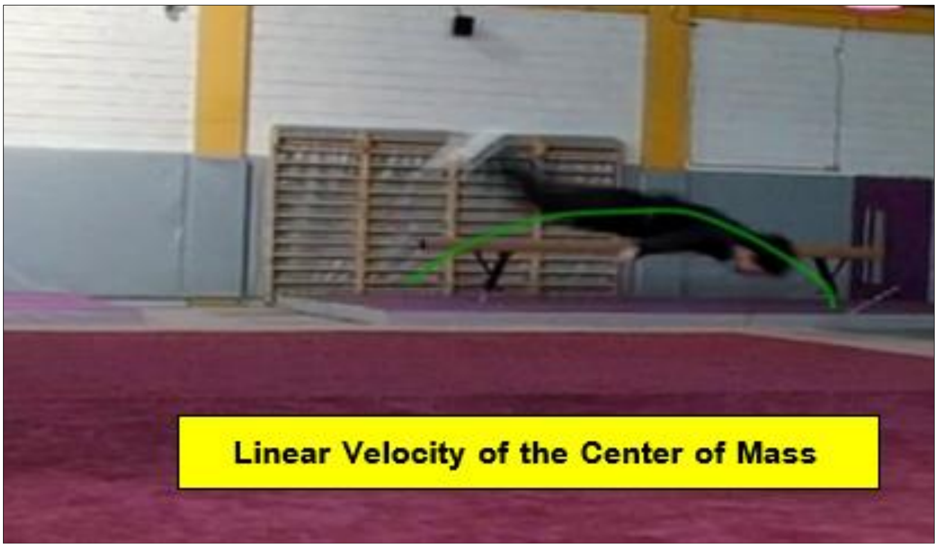


Fig 5: Show how to measure the peripheral velocity of the body's center of mass during the preparatory phase.

Angular variables

Angular variables in biomechanical analysis: Angles are among the fundamental variables upon which biomechanical analysis relies in studying kinetic performance. They represent the geometric relationship resulting from the intersection of two rays that share a common starting point. The importance of these variables lies in their ability to explain the quality and efficiency of movement, and to analyze physical positions during athletic performance. The following is an explanation of the most important angles used:

Hip Joint Angle: The angle between two imaginary lines, the first extending from the shoulder joint to the hip joint, and the second from the hip joint to the knee joint. This variable is measured during the forward body position and is used to determine the range of hip movement during performance. This contributes to assessing the extent of extension or flexion of this joint and its impact on the overall kinetic balance of the body, as illustrated in the following Figure.

Fig 6: Show how to measure the hip joint angle during the preparatory phase.

Knee joint angle: This is defined as the angle formed by the junction of the femur with the shinbone (tibia). It is a key indicator for measuring the degree of flexion or extension in the knee joint and plays an important role in understanding the effectiveness of the force generated during performance phases, such as takeoff or landing, as shown in the following figure:

Fig 7: Show how to measure the knee angle during the preparatory phase.

Landing Angle: The angle formed between the direction of body movement and the horizontal line at the moment the foot contacts the ground during landing. This angle is important in assessing landing efficiency, as it significantly affects body stability and prevents injury. The ideal landing angle is usually close to the vertical angle, which helps distribute the force resulting from landing evenly across the joints, as shown in the following figure:

Fig 8: Show how to measure the landing angle during the preparatory phase.

Rising Angle: This angle is measured between a line extending from the center of gravity to the point of contact with the horizontal surface during the initial rise. It is used as an important indicator for determining the efficiency of vertical movement and the extent to which it contributes to achieving the appropriate height during the jump or rise, as shown in the following figure:

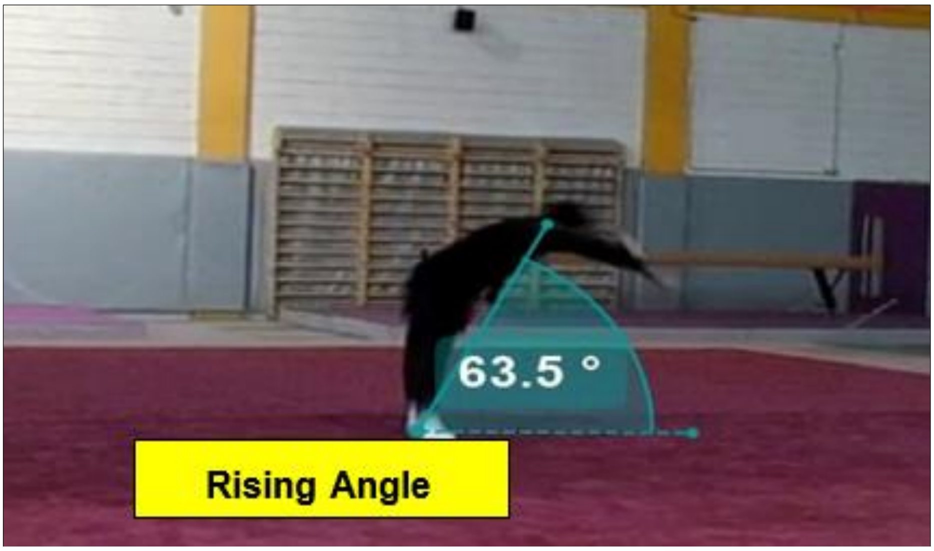


Fig 9: Show how to measure the rise angle in the preparatory phase.

Distance variables

Center of Mass Height: Defined as the vertical distance between the body's center of gravity and the ground, it is usually measured in centimeters. This height represents the point considered the center of the body's mass distribution, from which the total force applied to the body during movement is determined. This variable is accurately extracted through biomechanical analysis using digital measurement techniques or specialized software. It is a fundamental factor in interpreting the mechanics of balance and stability, as well as the effectiveness of the resulting force in jumping or vertical propulsion movements. The more appropriate and compatible the center of gravity height is with the nature of the performance, the more positively it reflects on dynamic balance and reduces energy loss during movement transitions. The center of gravity height is calculated using the following equation:

$H_{CM} = \sum \left(\frac{m_i \cdot h_i}{M} \right)$ as shown in the following figure:

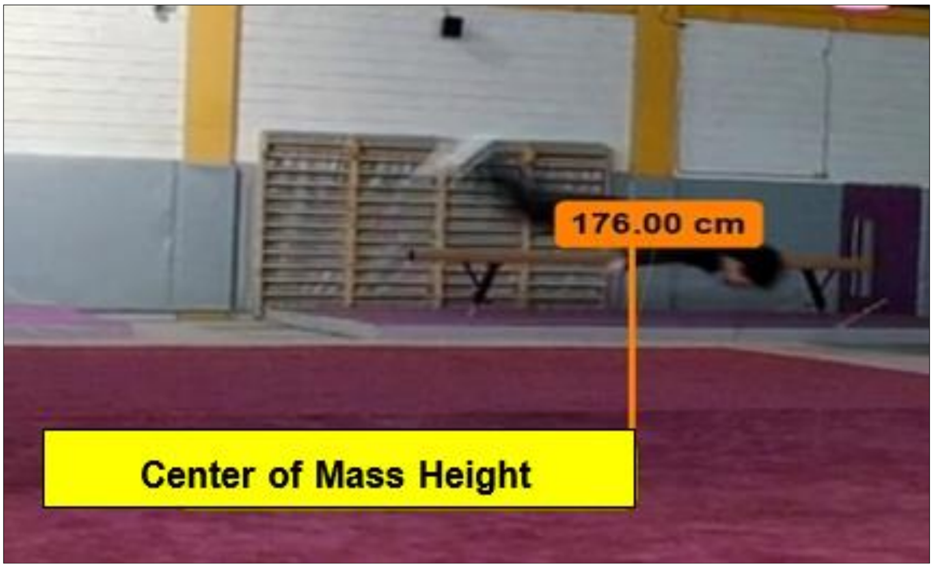


Fig 10: Show how to measure the height of the body's center of gravity.

Force-time curve variables

The force-time curve is one of the most prominent analytical tools in biomechanics. It is used to understand the dynamic relationship between the force produced by the body and the time required to perform a movement. This curve is drawn by representing force on the vertical axis (Y-axis) and time on the horizontal axis (X-axis), as shown in the following figure:

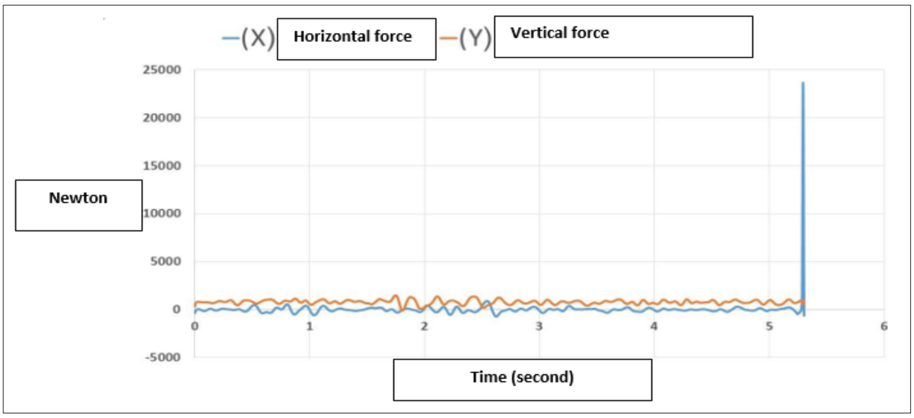


Fig 11: Show the force-time curve.

Push Time: Push time is defined as the period of time during which force is applied during the moment of support, i.e., the period during which the body is pushed. This variable is considered one of the fundamental factors affecting force production and achieving optimal performance in many athletic movements, such as jumping or sprinting. The formula for calculating push time can be calculated using the following relationship:

\text{Impulse} = F \times t.

Impact Time: Impact time is defined as the period of time during which force is applied when a body collides with another surface, from the moment of impact until the body reaches a state of complete stability. During this period, energy is exchanged between the body and the colliding surface, and forces are generated that affect the body's movement. This variable is extremely important in studying the effects of sports collisions (such as football, basketball, or jumping) and in assessing the level of force absorption or distribution within the body. Impulse Time Calculation Law: Impact time can be calculated using the impact equation (time effect), which is based on the principle of conservation of momentum: text {Impulse} = F \times t

Rate of Force Development (RFD):
Rate of force development (RFD) is an important biomechanical variable used to measure the body's ability to generate force quickly and efficiently during the initiation of movement. This rate is calculated using a Dynafoot device, which measures the force applied from the moment the upward push-off begins until the foot separates from the ground. This measurement is essential for analyzing kinetic performance, as it reflects the speed and flow of force produced by the athlete at the beginning of movement, which significantly impacts performance in activities that require rapid acceleration, such as running or jumping. Impulse Rate Calculation Law: RFD is calculated using the following equation:

RFD = \frac{\Delta F} {\Delta t}

Impact Force Rate:
Impact Force Rate is the variable used to measure the amount of force generated by the collision between the body and the surface in contact with it during the impact period. This rate depends on the instantaneous speed of change in momentum during the impact and is measured in units of Newtons per second. This variable is essential for understanding the effects of collisions in sports or movements that involve sudden changes in motion or direction, such as in football, basketball, and even kinetic sports. The impact force rate can be calculated using the following relationship:

F_{\text{impact}} = \frac{\Delta P}{\Delta t}

Biomechanical variables related to the skills studied on the floor exercise apparatus were calculated on a sample of Iraqi national team players, based on the kinematic groups that are considered an essential part of the technical requirements of floor gymnastics. These variables were calculated for the second group (forward acrobatic movements) and the third group (backward acrobatic movements), as these movements are characterized by the application of large propulsive forces during performance.
The apparatus is attached to the feet during acrobatic movements, allowing for the measurement of the propulsive force applied by the feet, a crucial factor in executing movements accurately and efficiently. Accordingly, the focus was on measuring the kinematic variables in these forward and backward acrobatic movements, which require strong propulsion to achieve optimal performance in balance and dynamic strength.
As for non-acrobatic movements, challenges were encountered in accurately measuring propulsive force, as these movements do not rely heavily on the feet as the primary source of force generation. Therefore, it was not possible to apply the same methods to measure the momentum of these types of movements. The variables were as follows:
"To analyze the research data and identify the results of the variables under study, the researchers used the statistical program (SPSS) along with the program (Excel) to extract the appropriate statistical treatments, which included: the arithmetic mean, standard deviation, and a t-test to analyze the differences between the averages and determine their statistical significance."

Results

Table 1: Shows the arithmetic mean, standard deviation and calculated t-value for the results of the straight front aerial jump skill variables with 2 turns.

Skill	Section	variables	Arithmetic mean	Standard deviation	T-Value calculated	Type Sig
Straight front aerial jump with 2 turns	Preparatory	Hip Angle	149,33	8,32	-1,36	Non sig
		Rise Angle	136	45,92	-0,314	Non sig
		Rate of impetus	1737,15	324,00	4.55	Sig
		Knee Angle	174,33	3,214	-0,83	Non sig
	main	Hip Angle	144,33	1,52	-11,59	Sig
		Knee Angle	148	16,37	-0,56	Non sig
	Final	Hip Angle	177,33	3,78	-0,40	Non sig
		landing angle	127	60,91	-0,28	Non sig
		(Impact Force Rate	2563,66	259,74	2,25	Non sig
		Center of Mass Height	2.36	0.472	7.351	Sig

Discussion

Table 1 shows the statistical estimates of the research sample's results related to the kinematic performance variables of the straight front aerial jump skill with a full rotation around the longitudinal axis during the preparatory section of the skill. The results showed that some variables, such as the hip angle, the take-off angle, the propulsion force rate, and the knee angle, were not statistically significant. In contrast, the results revealed a statistically significant effect in the hip angle during the main section of the skill. This is due to the crucial role played by the hip angle as an influential kinematic variable at this stage. The variable of the body's center of gravity height in the final section showed significant statistical significance, while the remaining variables in the preparatory, main, and final sections did not show significant significance. This discrepancy can be explained by several factors, including momentum generation and rotation. The hip joint is considered an essential element in generating the momentum necessary for rotation around the longitudinal axis during the main section of the skill. Effective performance requires achieving appropriate extension and flexion at the hip joint to ensure balanced rotation, control of the movement path, and the direct influence of the hip angle on the path of the body's center of gravity. It helps achieve the required altitude and appropriate speed during flight, thus ensuring a perfect landing. Precise control of the hip angle contributes to improving the athlete's stability during landing, enhancing the quality of technical performance and reducing the risk of errors or loss of balance. Therefore, the hip angle in the main part of the skill can be considered a crucial variable affecting the quality of performance, while the other variables do not show a similar significant effect across the various stages of the performance. (Mkaouer, B., *et al*., 2022) [11]. (Čuk I, Bučar Pajek M, 2021) [4], (Huang C, *et al*., 2021) [6]. The explanation for the insignificance of other variables in the preparatory part is that this part aims to prepare the body for the main movement. The kinematic variables in this stage may be similar across individuals, which reduces statistical differences and renders them insignificant. The hip angle is a pivotal element in the main part of the straight front aerial jump with a full twist, as it directly affects the quality of performance and rotation. We also note that the law of force propulsion indicates that the athlete must produce the greatest force in the shortest time, according to the following law:

Since impulse = momentum.
Impulse = F x N.

So force = impulse/(time)

Therefore, we note that the relationship between force and time is an inverse relationship, meaning that the more force is required, the less time the player must push. This is what we notice in the test variables (the Iranian player). If his pushing force is large compared to the sample, he obtained a greater height than the players (sample), which allowed him to perform the skills (aerial jumps) in a more fluid manner. The height of the body's center of gravity (Center of Mass Height) is one of the most important biomechanical variables that directly contribute to the quality of kinetic performance in gymnastics, especially in complex aerial skills that require a high level of balance and accuracy in executing rotations, as is the case in the skill of the straight front aerial jump with a full twist in the air. The statistical results showed significant significance for this variable, confirming its pivotal role in achieving kinetic efficiency and saving effort during performance. The height of the center of gravity during the flight phase is a decisive factor in determining the total flight time, thus allowing the jumper a greater opportunity to complete a full turn, while maintaining the kinetic alignment of the body without distortions that affect the degree of execution. (Aragón-Vargas LF, 2023) [2], (Luo Y, *et al*., 2020 [9], Sands WA & McNeal JR, 2002 [12], Knudson D, 2007) [7]. The direct relationship between the height of the center of gravity and flight time contributes to controlling the aerial time, which reduces the possibility of making errors during descent and gives the player sufficient time to complete his movement smoothly. On the other hand, this variable is essential for achieving dynamic balance, as it directly affects the path and direction of the aerial movement, which helps maintain the stability of the body during flight and control it upon descent. The optimal height of the center of gravity also contributes to enhancing kinetic economy by reducing the muscular effort required to direct the body, especially by the pivotal muscle groups, which reflects the efficiency and smoothness of performance. Furthermore, the height of the center of gravity is one of the factors influencing the take-off angle and movement direction, as controlling its location is reflected in the path (Artlett R., 2007, (Komi PV., 2000) [3, 8]. Launching and rotation in the air are also closely linked to reducing landing errors. The higher the center of gravity is in the airway, the better the ability to time the descent and precisely direct the lower extremities toward the ground. From the above, it is clear that the height of the body's center of gravity represents a vital determinant of aerobic performance in gymnastics. It is recommended to pay special attention to it when designing training programs to develop skills that include multiple or compound rotations. Controlling this variable effectively contributes to enhancing the quality of performance and avoiding technical errors that may affect the final result. By analyzing the kinematic path of the variables studied in the research sample and comparing it with the kinematic path of the Iranian player (the referee), clear differences in performance mechanisms emerge. This variation is evident in the shift in the body's center of gravity and the organization of movements during the skill execution. The results also reveal differences in performance speed between the studied sample and the test player, reflecting differences in neuromuscular control and kinetic coordination. These differences extend to the method of applying force and interacting with gravity during the performance, which affects the overall efficiency of executing the straight front aerial jump with a full twist. These differences indicate that kinematic and kinetic factors play a crucial role in achieving optimal performance, calling for improved training mechanisms to achieve more efficient performance.

Conclusions and Recommendations

Conclusions

The researchers concluded the following:

The analysis results revealed clear differences in the technical performance of the straight aerial jump with two turns between the Iraqi and Iranian national team players, represented by weaknesses in some biomechanical variables such as propulsion force and joint angles. These variables have proven important in improving performance quality, particularly center of mass and flight time, which are linked to international arbitration standards. The biomechanical analysis also revealed significant technical errors, along with variations in specific strength, force moments, and angular velocity, confirming their direct role in technical performance efficiency.

Recommendations

The researchers recommend: adopting training programs based on biomechanical analysis to enhance propulsion, angular velocity, and center of mass control; providing advanced analysis techniques to accurately evaluate performance and support training development; directing training to correct joint errors and flight time to increase efficiency and reduce competition; and enhancing technical cooperation and exchange of expertise to raise the level of competitive performance.

References

1. Abdullah. Biomechanics in sports: Practical applications to athletic performance. Riyadh: King Saud University, 2014.
2. Aragón-Vargas LF. Biomechanics of human movement. Cham: Springer, 2023.
3. Artlett R. Introduction to sports biomechanics: Analyzing human movement patterns. 2nd Ed. Champaign: Human Kinetics, 2007.
4. Čuk I, Bučar Pajek M. Movement mechanics in gymnastics: A review. Science of Gymnastics Journal. 2021;13(1).
5. Enoka RM. Aeromechanics of human movement. Champaign: Human Kinetics, 2008.
6. Huang C, Zhang X, Liu Y, Wu Y, Li H. Impact of center of mass displacement on aerial movement efficiency. Journal of Sports Biomechanics. 2021;20(4).
7. Knudson D. Fundamentals of biomechanics. New York: Springer, 2007.
8. Komi PV. Stretch-shortening cycle: A powerful model to study normal and fatigued muscle. Journal of Biomechanics. 2000;33(10):1197-1206.
9. Luo Y, Li X, Zhang Q, Wang J, Liu S. Influence of take-off kinematics on landing quality in gymnastics. Journal of Sports Research, 2020.
10. Mkaouer B, Tabka Z, Amara S, Hammoudi H. Kinematic analysis of acrobatic elements in gymnastics. Journal of Human Sport and Exercise. 2020;15(4):901-910.
11. Mkaouer B, Amara S, Hammoudi H, Tabka Z. Biomechanical parameters in elite gymnastics performance. International Journal of Sports Science and Coaching. 2022;17(4):652-660.
12. Sands WA, McNeal JR. Biomechanics of gymnastics techniques. Colorado Springs: United States Gymnastics Federation, 2002.
13. Winter DA. Biomechanics and kinetic control of human movement. Hoboken: Wiley, 2009.
14. Radisat ALZFS, Kurdi ALMD, Ziad. Comparison of the path of the body's center of gravity and the values of some kinematic variables when performing the forward aerial somersault skill on different apparatus among national gymnastics team players. Journal of Sports Science Applications. 2022;8(114):378-405.

Appendix 1

Shows the sample during the preparation of the research