Pubmedia Jurnal Pendidikan Olahraga Vol: 2, No 4, 2025, Page: 1-13

A Three-Dimensional Analytical Study of the Spike Skill in Volleyball According to Certain Biomechanical Motion Variables and Performance Technique Among the University of Tikrit Team Players

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DOI: https://doi.org/10.47134/jpo.v2i4.1706
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Received: 13-04-2025
Accepted: 20-05-2025
Published: 02-06-2025

Abstract: This research aimed to analyze the biomechanical and technical variables related to performance and to assess the efficiency and effectiveness of the smashing skill among volleyball players from Tikrit University. The researchers hypothesized that three-dimensional kinematic analysis could help identify specific kinematic variables and evaluate the efficiency of the smashing technique used by these athletes. To achieve this, the researchers adopted a descriptive approach utilizing the case study method, which was deemed most suitable for examining the biomechanical and technical elements of the smashing skill. The research sample consisted of four intentionally selected players from the Tikrit University volleyball team, all of whom participated in the Iraqi Universities Championship during the 2023–2024 academic year. These players were chosen specifically for their specialization in smashing, aligning with the study's objectives. The findings revealed that allocating the appropriate amount of time for performing a smash significantly enhances performance, with players who minimize execution time proving more effective in offensive play. Additionally, variations in the body's center of gravity were found to influence performance levels; players with a higher center of gravity are better positioned to reach higher points, thereby increasing their potential for delivering powerful and well-timed smashes. Based on these conclusions, the researchers recommended focusing on improving the timing of the smash by training athletes to increase the speed of coordination between the pass and the smash. Furthermore, emphasis should be placed on refining jump timing and faster positioning, especially for players who currently exhibit slower execution

Keywords: Biomechanical Analysis, Smashing Technique, Volleyball Performance

Introduction

The spike skill in volleyball is one of the fundamental aspects of player performance, playing a crucial role in a team's success and achieving positive results in matches. The University of Tikrit serves as an important center for the development of team sports and the enhancement of team levels to compete in inter-university tournaments. Its volleyball team represents an elite group of players striving for achievements at the university level.

The significance of this study lies in the analysis of one of the most essential offensive skills in volleyball—the spike—among the University of Tikrit team players. This is achieved by examining several key variables, including biomechanical motion variables and performance techniques. This analysis aims to provide a better understanding of these variables and their impact on the efficiency and effectiveness of the spike.

Biomechanics provides answers to many questions faced by coaches in various sports. Within the framework of performance analysis, this study may lead to a deeper understanding of the spike technique in volleyball, including the nature of movements in the arm, trunk, and other body parts, as well as their contribution to and impact on performance (Al-Fadhli, 2010: 31).

As a university committed to sports development and the enhancement of its players' skills, this study will offer new insights and valuable findings that can be used to develop training programs and improve team performance. The research significance lies in providing a scientific description of players' technical performance based on three-dimensional motion analysis. It will illustrate the sequential execution of movements for each player using cumulative video footage in a single frame and clarify motion paths and variable values through dotted analytical images.

Research Problem

Despite the importance of the spike skill in volleyball for team performance and achieving positive results, there is a lack of comprehensive understanding regarding the factors that determine the efficiency and effectiveness of this skill among the University of Tikrit team players. This deficiency is primarily due to the inability to analyze biomechanical motion variables and performance techniques and understand their impact on spike efficiency. The core research problem lies in the difficulty of evaluating player performance and identifying variable values due to the high speed of execution.

By addressing this issue, this study will provide an in-depth perspective on the variables affecting player performance in the spike skill. Consequently, it will pave the way for the development of advanced training programs aimed at enhancing the performance level of the University of Tikrit volleyball team players.

Research Objectives

- Analyzing biomechanical motion variables and performance techniques to clarify the efficiency and effectiveness of the spike skill in volleyball among the University of Tikrit team players.

- Identifying the movement model of the University of Tikrit team players' spike technique.

Research Hypothesis

Three-dimensional motion analysis helps in identifying certain kinematic variables and determining the efficiency of spike technique performance among the University of Tikrit volleyball team players.

Research Fields

- Human Field: University of Tikrit volleyball team players (male).
- Temporal Field: From April 12, 2024, to October 12, 2024.
- Spatial Field: Indoor hall at the University of Tikrit, College of Physical Education and Sports Sciences.

Definition of Terms

- Three-Dimensional Motion Analysis: A process that utilizes advanced technology, such as cameras and assisting equipment, to capture and analyze sports movements in three dimensions (Length, Width, and Height). This analysis allows for the description of body movement from all angles and provides an accurate understanding of movement dynamics (Winter, 2009, p. 189)
- Spike: Defined by researchers as one of the fundamental skills in volleyball and a key offensive technique where the ball is struck forcefully with precise timing and at an appropriate angle towards the opponent's court. The objective is to score a point by making it difficult for the opposing team to block or return the ball. The spike is typically executed following a set pass, with the player raising their hand and striking the ball at the highest possible point using the palm and fingers.

Methodology

The researchers adopted a descriptive method using the **case study** approach, as it is the most suitable for analyzing the biomechanical aspects and technique of the spike skill among the University of Tikrit volleyball team players. This method helps in accurately describing and collecting data on the studied variables and analyzing them in greater detail to understand the technical aspects of the players. This is achieved by conducting a case study on selected players from the University of Tikrit volleyball team.

Research Sample

The research sample was selected from the University of Tikrit volleyball team players who participated in the Iraqi Universities Championship for the academic year 2023-2024. Four players specializing in the spike skill were intentionally chosen based on their skill level, experience, and execution of the performance. These players were selected from a pool of twelve team members, ensuring a good representation of the kinematic and technical characteristics of the team. Thus, the sample represents 33.33% of the total team members.

Data Collection Methods

- Direct Scientific Observation: Observing the players during training and recording their technical spike performance.
- Personal Interviews: Conducting interviews with players, coaches, and assistants to discuss performance techniques and gather information about the players' participation in the championship.
- Video Analysis (Spike Skill Analysis): Reviewing video recordings to provide a detailed description of technical performance through observations using the APAS Menu 2020 motion analysis software.
- Literature Review and Sources: Examining and studying previous research related to volleyball and reviewing published studies relevant to the research content.

Equipment and Tools Used in Research

- Two iPhone 14 Pro Max devices: These devices were used due to their advanced specifications to document and analyze players' performance with high-quality recording.
- Fieldwork tools: Four calibration poles were used to set up the filming scene inside the court, along with two camera stands.

Research Experiment

The research experiment involved capturing the spike skill movements of the University of Tikrit volleyball team players. The focus was on collecting data using iPhone 14 Pro Max cameras to analyze the precise movements related to the spike skill. The experiment details are as follows:

- Experiment Date: April 14, 2024
- Time: 11:45 AM
- Location: Indoor sports hall at the University of Tikrit, College of Physical Education and Sports Sciences (Volleyball Court)
- Experiment Procedures: Four players from the University of Tikrit volleyball team were intentionally selected based on their performance level, as determined by the coaches.
- Video Recording: High-resolution recordings were taken using iPhone 14 Pro Max cameras. Each player's movements during spike execution were filmed from two perpendicular angles (90°) to ensure a comprehensive visual representation of the performance.
- Calibration for Analysis: A calibration cube (300 cm dimensions) was placed inside the court and filmed from perpendicular angles to compare actual measurements with recorded data. This helped in correcting any deviations and achieving higher accuracy and better image quality in the motion analysis.

Research Variables

The researchers selected the variables based on the study's objectives, which aim to analyze the biomechanical aspects and technique of the spike skill among the University of

Tikrit volleyball team players. These variables were determined through scientific discussions, field observations, and an initial analysis of player needs and volleyball skill requirements. The key variables include:

- Spike Performance Time: The time taken by the player to execute the spike, from the moment of takeoff to landing, measured in seconds.
- Spike Performance Distance: The distance between the takeoff foot and the landing foot after executing the spike.
- Body Center of Gravity: The vertical distance of the body's center of gravity during spike execution, measured in meters.
- Trajectory Length of the Center of Gravity: The linear distance traveled by the body's center of gravity from takeoff to landing, measured in meters.
- Player's Speed Based on Center of Gravity: The speed covered by the player's center of gravity from takeoff to landing, measured in meters per second.
- Ball Contact Height with the Striking Hand: The highest point reached by the player when striking the ball, measured in meters.
- Knee Joint Angle (Coordinates): The angle determined based on the three motion axes (X, Y, Z) within the player's movement coordinate system. This represents the angle formed between the knee joint and the movement vector in the direction of the player's motion, measured in degrees.
- Elbow Angle: The angle between the forearm (elbow to hand) and the upper arm (shoulder to elbow) at the highest takeoff point, measured in degrees.
- Ball Impact Angle: The angle between the horizontal line and the direction of the ball's movement over the net, measured in degrees.

Result and Discussion

Presentation of Results

This chapter presents the results of the studied variables, which constitute the core content of the research. The analysis was conducted using **three-dimensional motion analysis** of the four selected players. Table (2) below illustrates the kinematic variables related to the spike skill execution:

Table 1. Kinematic Variables of Players Performing the Spike Skill

Variables	Unit of Measurement	Player 1	Player 2	Player 3	Player 4
Spike Execution Time	Seconds	0 - 1.11	0 - 1.27	0 - 1.13	0 - 1.02
Spike Execution Distance	Meters	0 - 2.28	0 - 2.03	0 - 2.44	0 - 1.75
Spike Execution Speed	m/s	0 - 1.90	0 - 1.91	0 - 2.15	0 - 1.71
Body Center of Gravity Height	Meters	0.9 - 1.84	1.1 - 1.74	1.2 - 1.80	0.85 - 1.75
Trajectory Length of the Center of Gravity	Meters	0 - 2.46	0 - 2.24	0 - 2.77	0 - 2.08
Player's Speed Based on Center of Gravity	m/s	2.22	1.86	2.50	2.05
Ball Contact Height with the Striking Hand	Meters	2.64	2.57	2.59	2.58
Knee Joint Angle (Coordinates)	Degrees	-83 - 67	-45 - 61	-59 - 63	-39 - 51

Variables	Unit of Measurement	Player 1	Player 2	Player 3	Player 4
Elbow Angle	Degrees	97	102	112	100
Ball Impact Angle	Degrees	-48	-33	-36	-26

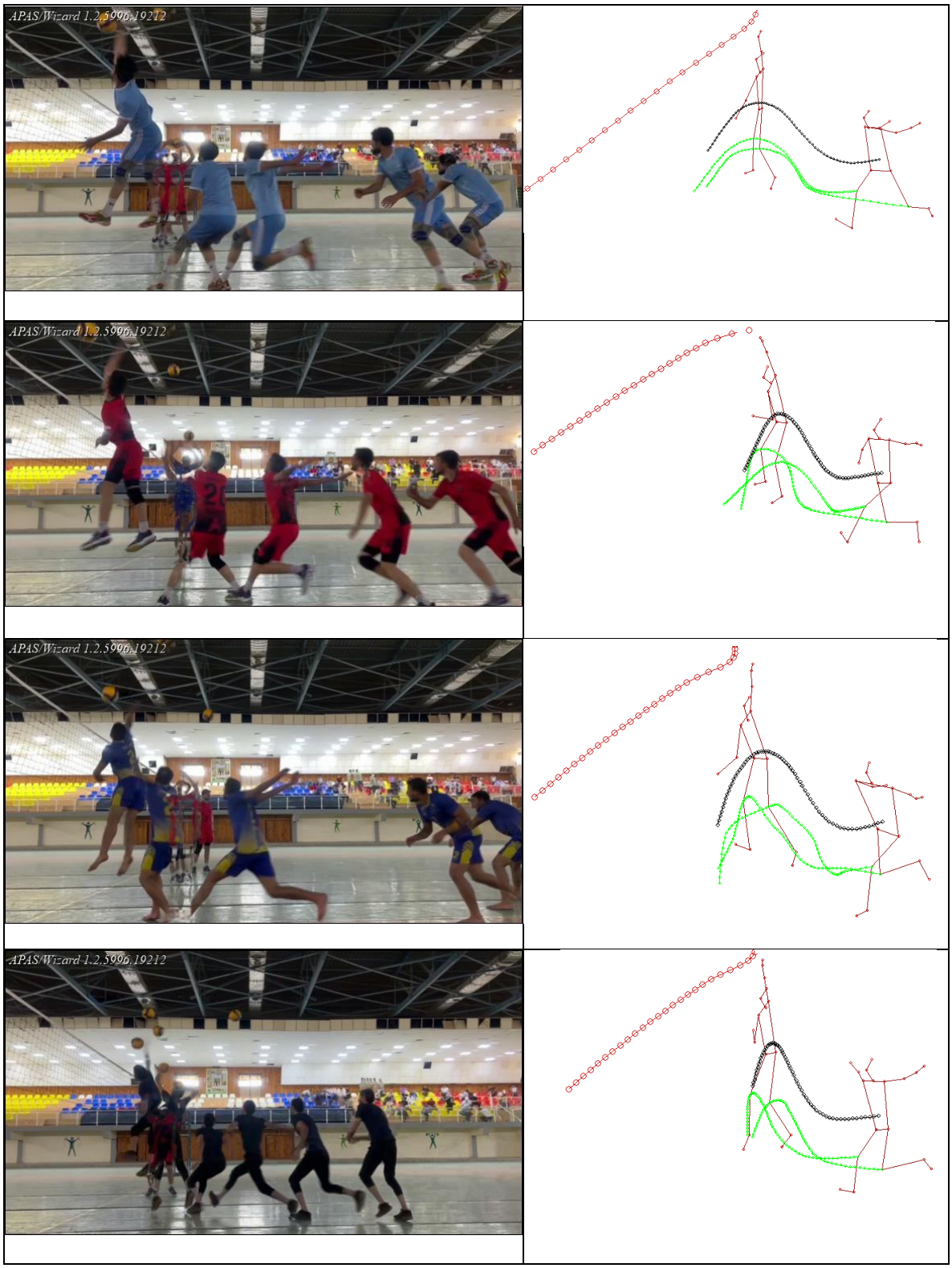

Figure 1. Images of cumulative motion analysis segments and some movement trajectories of performance.

Discussion

The researchers would like to emphasize that they have limited their analysis to motion analysis and the presentation of variable results without providing additional scientific elaboration. They believe that excessive additions, given the limited resources, could complicate or hinder the improvement process. However, by focusing on the fundamental variables, this study can serve as the foundation for a future series of studies and additional insights once the apparent weaknesses are addressed.

The first variable examined is the time taken by the player from the moment they decide to perform the spike until its complete execution (from the start of movement to the moment of ball contact). The results indicate variations in execution time among the players, with some requiring more time than others to achieve an optimal spike. The researchers suggest that this variation depends on each player's jumping technique. Although the differences are minor, the analysis highlights the ideal execution time, which is around 1.10 seconds, as the most stable performance benchmark. This emphasizes the importance of timing, where players should focus on correcting their execution by aligning their spike timing with proper positioning, jump timing, and coordination between passing and spiking—key factors for achieving the best timing.

The second variable represents the distance covered by the player during takeoff and landing when executing the spike. This distance starts from the moment the player takes off in preparation for the spike and ends when their feet land on the ground after execution. The researchers note that if the distance between the feet is large, it indicates that the player covers a significant distance during takeoff or landing, suggesting a more powerful or extensive movement during the jump. This demonstrates the player's ability to execute a strong jump while simultaneously incorporating lateral or forward movement before or after landing. The interaction between takeoff and landing (from both feet) reflects push-off strength and the ability to transfer motion during the spike. The researchers conclude that players who cover greater distances exhibit better jump height and control during landing, allowing them to execute stronger and more effective spike shots.

The third variable is the speed of spike execution, which measures how quickly a player performs the spike. Speed is determined by the distance covered over the time taken, impacting on the player’s ability to reach the ball and increasing their chances of executing an optimal spike.

The fourth variable is the height of the body's center of gravity, which the researchers highlight as a critical factor because it affects the player's jumping ability and control. A higher center of gravity allows for more effective spike execution. The researchers analyzed the minimum and maximum values for this variable. The lower height (ranging between 0.85 and 1.2 meters) represents the lowest point the center of gravity reaches during preparation or landing, or in cases of imbalance or reduced strength during movement. The higher value represents the peak height reached by the center of gravity during takeoff. The greater this height, the better the player's ability to reach higher contact points, improving their spike effectiveness.

The fifth variable is the trajectory length of the body's center of gravity in volleyball, a measure of the distance the center of gravity travels during the player's movement in the air, from takeoff to landing after executing the spike. The researchers view this variable as an indicator of the body's coordination and dynamic movement during the jump. It provides insights into the player's ability to maneuver in the air and control their center of gravity, which contributes to achieving optimal performance during the spike.

The sixth variable is the player's velocity in relation to their center of gravity, which determines the player's movement speed during execution, particularly at moments of takeoff and landing. This variable is calculated based on the speed of center-of-gravity displacement and reflects the player's efficiency in airborne movement. Figure 2 illustrates the linear trajectories of center-of-gravity values for each player.

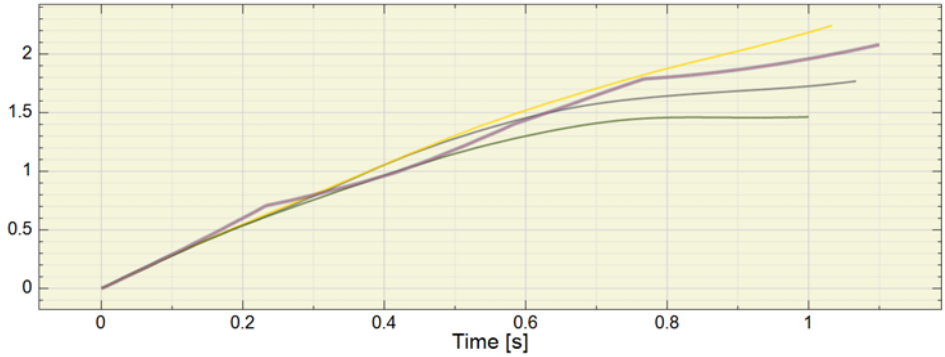

Figure 2. illustrates the linear trajectories of the body's center of gravity values.

The seventh variable is the height of the ball contact point with the striking hand. The researchers consider this variable as a key indicator that determines the maximum height the striking hand reaches when executing the spike or hitting the ball during a jump. This height is crucial as it reflects the player's ability to elevate in the air and strike the ball from a higher position, which enhances the power and difficulty of the spike for the opponent. Figure 3 illustrates the results of the maximum height reached by each player.

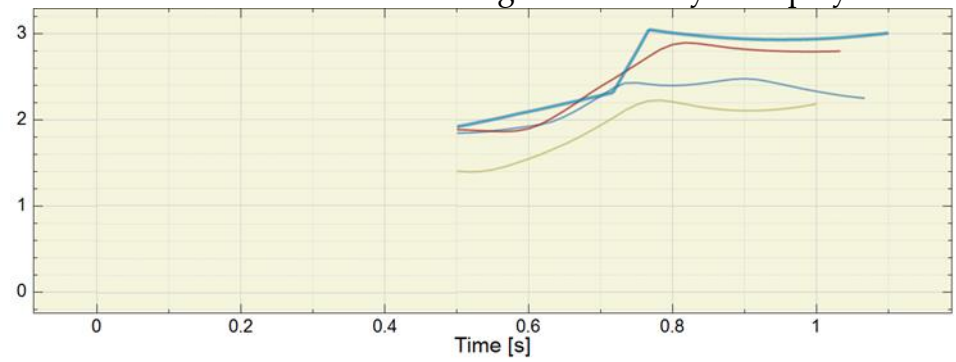

Figure 3. illustrates the maximum height reached by each player's striking hand when hitting the ball.

The eighth variable is the projection angle, which is considered one of the important indicators in analyzing movement performance, particularly in sports like volleyball. The researchers have discussed this angle despite the limited studies addressing this type of variable. According to the researchers, the projection angle is the angle determined between the knee joint and the movement vector, reflecting the player's motion direction within the

movement space. This angle is calculated using a three-dimensional coordinate system (X, Y, Z) based on the body's movement along the three axes. The results showed positive values for the angle during the preparation, push, and hit phases, and negative values during the landing phase. Figure 4 illustrates this.

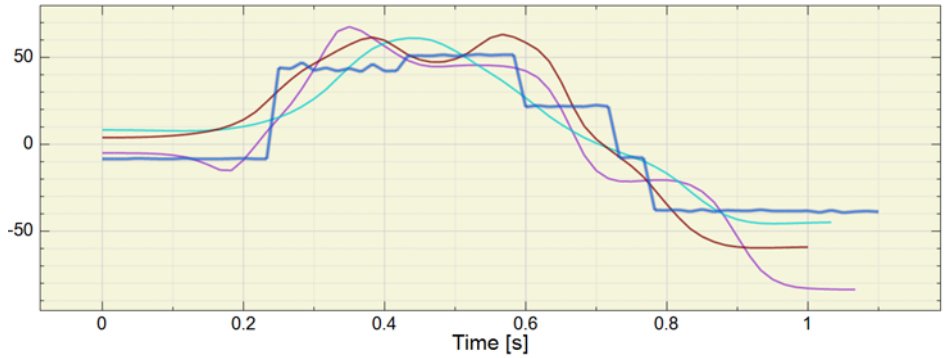

Figure 4. shows the results of the projection angle coordinates at the knee joint.

Tenth Variables: The angle of elbow flexion is an indicator of how prepared the player is for the spike. A smaller elbow angle indicates that the arm is more extended, while a larger angle suggests that the arm is more bent, preparing for the strike. Researchers believe that the elbow angle at the highest point plays a significant role in determining how the strike is performed. If the angle is smaller than 90°, it may indicate that the player is not fully utilizing the maximum muscle stretch of the arm to enhance power. Conversely, an angle larger than 90° indicates that the player is in a position that allows for greater use of the arm muscles' strength in executing the strike.

Tenth Variables: The angle of ball contact, which is formed between the direction the ball travels or its trajectory and the horizontal or ground line at the point of contact. This angle plays a significant role in determining the attacking angle or the direction in which the ball is directed toward the opponent's area. Researchers (Abbas Fadel Jawad and Abbas Ali Azab, 2021) emphasize that the spike is one of the effective attacking skills that significantly contribute to scoring for the team. They also highlight the importance of intelligence and the correct reading of game conditions by the spiker, knowing when and how to strike the ball to overcome the block effectively. The study shows that the spiker plays a pivotal role in achieving offensive superiority, as their skills can raise the team's offensive performance, thus increasing the chances of winning. Researchers assert that offensive integration is key to success in volleyball, and the spiker is one of the main factors in determining the team's success (Jawad and Azab, 2021: 208).

The results of the study by Maad Maan Alawi and Moein Ali Obeid (2019) highlighted the importance of trunk movement in improving the accuracy of the spike. This is because the rotation of the trunk around the longitudinal axis enhances the torque transmitted to the striking arm, contributing to increased strike force, and consequently, the ball's speed. Moreover, the player can control the ball's trajectory despite the high speed of the striking arm due to the coordination between the trunk, shoulder, arm, wrist, and hand, allowing for effective ball direction above the block. The study also pointed out the importance of the trunk's motion path length in achieving greater ball speed upon impact,

which is essential for speed and accuracy in the skill. As for other variables, such as the horizontal distance between the player's takeoff point and the ball, angular and peripheral speed of the striking arm, flight angle, and vertical hip distance, the results showed that players made errors during performance that affected their significance. These errors were reflected in the lack of coordination, such as excessive stepping distance during the approach or incorrect stopping and poor coordination between approach speed and jump, which weakened the effect of these variables on performance (Alawi and Obeid, 2019: 853).

The sports technique expert Duane Knudson (2013) mentioned that the spike in volleyball is considered one of the fundamental offensive skills that heavily relies on biomechanical variables to achieve maximum power and accuracy in the strike. These factors include:

- Trunk Movement: The trunk plays a fundamental role in providing the speed necessary to generate torque that is transferred to the striking arm. The rotation around the trunk's longitudinal axis enhances the force transferred by the arm to the ball, thereby increasing the strike's momentum.
- The Striking Arm: As the trunk's rotational speed increases, so does the peripheral speed of the arm, contributing to greater strike force.
- Ball Control: Ball control is a crucial aspect of the spike. Despite the high speed of the striking arm, the player must maintain control of the ball through coordination between the trunk, shoulder, and arm.
- Other Biomechanical Effects: Knudson also addresses the importance of the correct arm angle during the strike and its impact on directing the ball accurately above the block. Additionally, the perfect timing for jumping and approaching before execution, as well as speed, power, and accuracy in the spike, depend on biomechanical coordination between different body parts. Control of body movement and proper timing throughout the various phases, from the approach to the strike, enhances the effectiveness of this skill in achieving offensive success in volleyball (Duane, 2013: 126).

Conclusion

- Optimal Timing in the Spike: The effective use of time in executing the spike enhances performance. A player who can reduce the time taken to perform the strike will be more effective in attack.
- Center of Gravity Variables: The center of gravity variables plays a significant role in determining performance levels. A player who achieves a higher center of gravity will have an advantage in reaching higher points on the court, which enhances their ability to execute powerful and effective spikes and achieve better timing.
- Elbow Angle at the Peak of the Jump: The elbow angle at the peak of the jump is an important indicator of how much the player benefits from muscular strength during the strike. Larger angles generate greater force.
- Knee Joint Projection Angle: The knee joint projection angle helps determine how well the knee movement coordinates with the rest of the body during the jump and the strike.

An optimal angle reflects the player's ability to execute smooth and coordinated movement between the legs and arms.

Recommendations

- Improve Strike Timing: Enhance strike performance by training to increase the speed of the interaction between passing and spiking.
- Focus on Jump Timing and Positioning: Concentrate on improving jump timing and positioning, especially for players showing longer response times.
- Enhance Center of Gravity Variables: Strengthen the center of gravity variables, as they reflect the overall movement, which involves not just jumping or landing but also the dynamic components of the spike.
- Knee Joint Projection Angle Development: Performance development should be based on the values of the knee joint projection angle.
- Maintain an Optimal Elbow Angle: Ensure an appropriate elbow angle for the spike to help the player direct the ball more accurately toward difficult areas of the opponent's court.
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