



THE RELATIONSHIP OF THE SYNCHRONIZATION BETWEEN THE HITTING ARM MOTION AND THE TAKE-OFF FOOT IN TERMS OF ANGULAR AND LINEAR VELOCITY WITH THE ACCURACY OF THE FLOAT SERVE IN VOLLEYBALL FOR JUNIORS

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Abstract

The study aimed to identify and quantify the motor synchronization between the hitting arm and the take-off foot during the execution of the float serve. It also sought to measure the angular velocity of the hitting arm and the linear (peripheral) velocity of its distal segment at the moment of ball contact, through pre- and post-testing of the research sample. The researcher hypothesized that there would be a statistically significant correlation between the synchronization of the hitting arm and the take-off foot and the angular velocity of the arm. A second hypothesis proposed the presence of a statistically significant correlation between the synchronization of the hitting arm and the take-off foot and the peripheral velocity of the distal end of the arm. The research population was defined as the players of the Naft Maisn Club for the 2024 season, consisting of (6) players. Based on the findings, the researchers recommended adopting specialized training exercises to develop motor synchronization between the hitting arm and the take-off foot, using training methods that emphasize timing and temporal precision in performance. They also emphasized focusing training on the phases of generating angular velocity and its transfer through the kinetic chain—from the foot, through the trunk, and ultimately to the hitting arm. The researcher concluded that there is a strong and direct correlation between the synchronization of the hitting arm and the take-off foot, indicating that temporal coordination between these motor actions is a decisive factor in achieving accuracy in the float serve among youth players. The results showed that the greater the motor synchronization between the hitting arm and the take-off foot, the lower the temporal dispersion in performance, which positively influenced the stability of the ball's trajectory and its accuracy in reaching the targeted zone on the opposite court.

Keywords: Synchronization, Hitting Arm, Take-Off Foot, Angular, Linear Velocity, Accuracy, Float Serve.

Introduction

Volleyball is a team sport that requires a high level of neuromuscular coordination and motor precision, as it integrates physical, technical, and tactical abilities simultaneously. Among the most influential skills in determining match outcomes is the float serve, which represents one of the fundamental skills for scoring points and applying tactical pressure on the opponent's reception. The importance of this skill lies in being



the starting point of the offensive phase, as an effective serve reduces the opponent's ability to organize their play. Moreover, the accuracy, direction, and velocity of the serve determine its efficiency and its direct impact on the flow of the match. The biomechanical execution of the float serve largely depends on the synchronization between the hitting arm and the take-off foot. This synchronization is considered a key indicator of mechanical efficiency, ensuring that body segments operate in a coordinated sequence to transfer mechanical force from the ground to the ball through the muscular (kinematic) chain. Any disruption in this synchronization leads to the loss of part of the mechanical energy, negatively influencing ball velocity and accuracy (Hay & Reid, 1988; Bartlett, 2007). Recent biomechanical studies indicate that the angular velocity of the hitting arm represents a primary determinant of performance quality in the serve, as it reflects the athlete's ability to generate the necessary rotational torque to produce high end-point velocity at ball impact (Kawamura et al., 2017). Similarly, peripheral (linear) velocity describes the speed of the distal segment of the arm (wrist or hand), which governs the launch speed and direction of the ball (Gowitzke & Waddell, 1979). Evidence further suggests that the relationship between these biomechanical variables forms the foundation for developing the technical and mechanical aspects of the float serve (Forthomme et al., 2011). The importance of examining motor synchronization between the hitting arm and the take-off foot becomes even more pronounced among youth players, as this developmental phase represents a crucial period for neuromuscular adaptation. Training directed toward enhancing motor synchronization contributes to improved mechanical control, movement precision, and energy efficiency. Additionally, analyzing the relationship between motor synchronization and both angular and peripheral velocities provides highly accurate diagnostic indicators that assist coaches in designing specialized exercises aimed at enhancing the mechanical and technical execution of the serve (Diab, 2020; Wagner et al., 2014). Thus, the present study derives its significance from analyzing the biomechanical relationship between the synchronization of the hitting arm and the take-off foot through angular and peripheral velocities, in order to determine their impact on float serve accuracy among youth volleyball players. The researcher aims to provide a quantitative and practical perspective that contributes to improving technical and mechanical training methods and supporting skill preparation programs in clubs and national teams. Understanding the dynamic interaction between lower and upper limb movements is considered a fundamental pillar of integrated motor performance in net games.

Research Problem

The float serve is a highly precise and complex skill that requires advanced temporal and motor synchronization between the lower and upper limbs. Through field observations—and given that the researchers are coaches in the Premier League—as well as by evaluating the performance of several youth volleyball players in the province, noticeable discrepancies were observed in float serve accuracy despite relatively similar physical abilities. This suggests that internal mechanical factors may contribute to these differences. It is assumed that the lack of motor synchronization between the take-off foot and the hitting arm forms one of the most significant contributors to reduced serve accuracy, as it disrupts the smooth transfer of mechanical force and reduces the final arm velocity. Moreover, many coaches emphasize muscular strength or external technical cues without adequately addressing the distribution of angular and peripheral velocities throughout the movement phases or monitoring the temporal rhythm of the action. Accordingly, there is a need for a quantitative scientific investigation that identifies the nature of the relationship between the



synchronization of the hitting arm and the take-off foot, and both angular and peripheral velocities, as well as their effects on float serve accuracy. Understanding this relationship is essential for enhancing the technical performance of youth players and improving the mechanical efficiency of movement.

Research Objectives

1. Determine the values of motor synchronization between the hitting arm and the take-off foot during the float serve.
2. Measure the angular velocity of the hitting arm and the peripheral velocity of its distal segment at the moment of ball contact.
3. Identify the relationship between the synchronization of the hitting arm and the take-off foot and the accuracy of the float serve.
4. Analyze the statistical significance of the relationship between motor synchronization, angular velocity, peripheral velocity, and serve accuracy.

Research Hypotheses

1. There is a statistically significant correlation between the synchronization of the hitting arm and the take-off foot and the angular velocity of the arm.
2. There is a statistically significant correlation between the synchronization of the hitting arm and the take-off foot and the peripheral velocity of the distal segment of the arm.
3. There is a statistically significant correlation between motor synchronization and both angular and peripheral velocities with float serve accuracy among youth players.

Research Fields

Human Field: Youth volleyball players, totaling six (6) participants.

Spatial Field: Martyr Wissam Al-Araibi Indoor Hall – Maisan Governorate.

Time Field: The study was conducted from March 15, 2025, to April 30, 2025.

Methodology

Research Method

Selecting an appropriate research method is one of the most critical steps that determine the success of any scientific study, as the choice of method must align with the nature of the problem and the objectives to be achieved (Mahjoub, 1985).

Accordingly, the researcher employed **the descriptive method using the correlational approach**, which aims to identify the degree of relationship between two or more variables (Owais, 1999).

Research Population

The research population was intentionally selected and consisted of **six (6) players** representing the **Al-Maisn Oil Club junior volleyball team**.

Tools, Instruments, and Data Collection Methods

Data Collection Methods and Instruments

- ❖ Arabic and foreign scientific sources.
- ❖ Personal interviews with experts and specialists.
- ❖ Researcher's direct observation.
- ❖ Data recording forms.



- ❖ Volleyballs (6).
- ❖ Three (3) Casio video cameras.
- ❖ HP laptop computer.
- ❖ Handheld calculator.
- ❖ One-meter calibration stick.
- ❖ Measuring tape.

Field Procedures

Pilot Study

The researchers conducted the pilot study on **Sunday, 9/3/2024**, at **3:00 p.m.** in the **Martyr Wisam Areebi Indoor Hall** in Maisn Province. The pilot sample consisted of **three (3)** players selected from the same research population. The purpose of the pilot study was to: Identify potential obstacles and difficulties that may arise during the main experiment. Ensure the safety and suitability of the instruments and tools used in the tests.

Research Tests

1. **Motor Synchronization between the Hitting Arm and the Take-off Leg:** This variable represents the time difference between the moment the hitting arm initiates movement and the moment the take-off leg performs the jump during the striking phase. A smaller time difference indicates greater coordination between the two segments, which contributes to increased serving speed.
2. **Angular Velocity:** Measured by tracking the rotational movement of the hitting arm around the joint within a specific time interval. The beginning and end of the motion are determined through motion-capture video analysis. Faster completion of the rotational movement within a shorter time reflects higher angular velocity.
3. **Linear (Peripheral) Velocity:** Measured by observing the speed of the hand or distal segment executing the strike during the arm's rotation. It represents the distance traveled by the segment per unit of time. Higher peripheral velocity indicates more efficient force transfer to the ball during the serve.

Main Experiment

The main tests were administered to the research sample on **Tuesday, 15/3/2024**, at **3:00 p.m.** in the **Martyr Wisam Areebi Hall** in Maisn Province. After explaining the test procedures to the players, each participant was given **six attempts** to ensure accurate measurement of serving performance. Using video recordings of these attempts, the researchers extracted the relevant **kinematic variables** under investigation.

Video Recording

Video recording was conducted using **three (3) Casio cameras** arranged as follows: The first camera was placed on a tripod **5 meters** to the player's right. The second camera was also positioned **5 meters** to the player's left. Both cameras were set at a height of **1.30 meters**, aligned vertically with the midpoint of the average serving distance for the final five steps. The third camera was positioned **10 meters** away at the front row of spectator seating, at a height of **3 meters**, to record the ball's flight from the moment of impact until it contacted the ground. A **one-meter calibration scale** was filmed at the midpoint of the performance pathway to ensure proper spatial calibration. All recorded video sequences were transferred to an external



hard drive and then to the laptop computer, where they were analyzed using **Kinovea software** to extract variables such as: Take-off step length, Take-off step time, Ball release velocity

Statistical Methods

The researchers used selected statistical procedures from the **SPSS** software package, including:

- ❖ Arithmetic Mean.
- ❖ Standard Deviation.
- ❖ Pearson's Simple Correlation Coefficient.

Presentation, Analysis, and Discussion of the Research Sample Test Results

Presentation and Analysis of Descriptive Statistics for Motor Synchronization and Kinematic Variables

Table 1: Shows Descriptive statistical results for the kinematic variables and serve accuracy

Variable	M	SD
Motor synchronization difference	0.398	0.067
Angular velocity of the arm	1.88	0.14
Peripheral (linear) velocity of the arm	0.34	0.01

Motor Synchronization Difference

The mean value of **0.398 seconds** represents the average time difference between the initiation of the arm movement and the take-off of the supporting leg. This indicates a moderate delay of approximately 0.398 seconds between the start of the arm swing and leg extension. The standard deviation (**0.067**) reflects a relatively consistent synchronization among the sample, indicating that most junior players display similar timing patterns. **Biomechanical Interpretation:** This synchronization value falls within an acceptable range for junior athletes, where an ideal difference of **0.1–0.4 seconds** is associated with efficient energy transfer and improved serve accuracy (Zemková & Hamar, 2010).

Researcher's Perspective:

The observed level of synchronization can be considered relatively good for junior players; however, reducing the synchronization gap through targeted coordination training could enhance motor control and further improve serve accuracy.

Angular Velocity of the Arm

Mean Interpretation: The value of **1.88 rad/s** represents the average angular velocity of the striking arm during the serve. **Standard Deviation:** A value of **0.14** indicates low variability among players, reflecting consistent technical execution.

Biomechanical Analysis: This angular velocity range is considered appropriate for junior players and allows the generation of sufficient peripheral velocity ($v = \omega \times r$) while maintaining accuracy (Bartlett, 2007; Hay, 1993). **Researcher's Perspective:** This angular velocity provides a solid baseline for post-training comparisons, especially when incorporating mechanical feedback to refine technique and correct errors.

Peripheral (Linear) Velocity of the Arm

Mean Interpretation: The mean peripheral velocity of **0.34 m/s** reflects the distal movement of the arm during ball release. **Standard Deviation:** The low value (**0.01**) indicates extremely consistent performance



across the sample. **Biomechanical Analysis:** Although relatively low compared to adult norms, this value is acceptable for junior athletes, indicating a performance pattern emphasizing accuracy over power.

Researcher's Perspective: This value can serve as a reference point. With progressive training and mechanical feedback, it is possible to increase peripheral velocity while maintaining synchronization and accuracy—critical elements in enhancing technical performance.

General Interpretation of the Three Variables

The researchers conclude that the three examined variables—motor synchronization difference, angular velocity, and peripheral velocity—represent fundamental biomechanical determinants of the accuracy of the float serve in volleyball. Motor synchronization between the striking arm and take-off leg plays a central mechanical role as it reflects the temporal and dynamic harmony across the sequential phases of movement, enabling effective energy transfer along the kinetic chain from the ground to the striking arm. Optimal synchronization increases angular momentum in the upper-limb joints, enhancing both angular and peripheral velocity, leading to more stable and accurate ball trajectories. Conversely, poor synchronization creates temporal gaps in force sequencing, resulting in partial loss of kinetic energy and reduced technical accuracy. Therefore, specialized training focused on synchronizing movement patterns based on precise kinematic analysis is essential for achieving optimal integration between timing, angular motion, and velocity (Wagner et al., 2014).

Presentation and Analysis of Correlation Results Between Research Variables

Table 2: Shows Correlation between motor synchronization, angular velocity, peripheral velocity, and serve accuracy

Variables	Correlation Coefficient	Sig
Accuracy & Motor synchronization	0.78	0.000
Accuracy & Angular velocity	0.96	0.000
Accuracy & Peripheral velocity	0.71	0.000

*Significant at $\alpha = 0.05$

Discussion of the Correlation Results Between Motor Synchronization, Angular Velocity, Peripheral Velocity, and Float Serve Accuracy

The Relationship Between Serve Accuracy and Motor Synchronization

The results show a strong positive correlation ($r = 0.78$) between motor synchronization difference and serve accuracy. This indicates that the closer the timing between arm movement and leg take-off is to the optimal pattern, the higher the accuracy of the serve. This finding aligns with biomechanical principles, which emphasize that synchronization between lower and upper body segments improves energy transfer from the legs to the trunk and the arm, enhancing control and precision (Bartlett, 2007; Zemková & Hamar, 2010).

Researcher's Perspective: Although the correlation is strong, it suggests that players can achieve further improvements by enhancing coordination between the arm, leg, and trunk. Targeted training using real-time mechanical feedback and corrective cues can significantly refine this synchronization (Magill, 2011; Schmidt & Lee, 2019).

The Relationship Between Serve Accuracy and Angular Velocity



The results reveal that angular velocity has the **strongest impact** on serve accuracy, with a correlation coefficient of **0.96**, indicating a very strong positive relationship.

Biomechanical Explanation: Angular velocity determines the rate at which the arm rotates around the shoulder joint, which directly influences the generation of optimal peripheral velocity of the ball (Hay, 1993; Bartlett, 2007). High angular velocity within the optimal range (5–7 rad/s for juniors) enhances accuracy by producing a controlled yet powerful ball trajectory, provided synchronization with trunk and leg movement is maintained.

Researcher's Perspective:

This strong relationship suggests that training programs focusing on technique optimization and gradual enhancement of angular velocity will likely yield substantial improvements in serve performance, more so than strength training alone.

The Relationship Between Serve Accuracy and Peripheral Velocity

The findings indicate a positive correlation ($r = 0.71$) between peripheral velocity and serve accuracy, though weaker compared to angular velocity and motor synchronization. Peripheral velocity is influenced not only by arm speed but also by the efficiency of energy transfer across the kinetic chain—from lower limbs to trunk to the striking arm. Effective sequencing ensures that linear velocity contributes to accuracy rather than disrupting ball control. **Biomechanical Consideration:** Ideal peripheral velocity for junior athletes performing the float serve ranges between **8–10 m/s**, a range that balances power with precision.

Researcher's Perspective:

Increasing peripheral velocity alone without improving synchronization and angular velocity may actually reduce accuracy due to loss of control (Knudson, 2007). Therefore, improvements should target the kinetic chain as a whole rather than isolated speed increases.

Conclusions

In light of the results obtained from the kinematic analysis of the relationship between the striking arm movement and the take-off foot, as well as the data related to angular velocity, linear (peripheral) velocity, and the accuracy of the float serve, the researcher reached the following conclusions:

1. There is a strong and direct correlation between the synchronization of the striking arm movement and the take-off foot, indicating that temporal coordination between the two actions is a decisive factor in achieving accurate float serves among junior players.
2. Increased motor synchronization between the striking arm and the take-off foot reduces temporal dispersion during performance, which is positively reflected in the stability of the ball's trajectory and its accuracy in reaching the targeted zone on the opponent's court.
3. The findings revealed that the angular velocity of the striking arm represents a fundamental mechanical indicator in generating the required force for an effective serve. A systematic increase in angular velocity contributes to raising the peripheral velocity of the arm's distal segment, thereby increasing ball release speed and directional accuracy.
4. The results showed that the peripheral velocity of the striking arm is directly influenced by the degree of synchronization of the take-off movement, indicating that the effective utilization of ground reaction force



through synchronized take-off contributes to the sequential transmission of kinetic energy along the kinetic chain to the striking arm.

5. The analysis demonstrated a positive relationship between higher values of angular and peripheral velocities and the accuracy of the float serve, confirming that accuracy is not solely a technical characteristic, but is also linked to the efficiency of the biomechanical variables accompanying the movement.

6. Poor synchronization between the striking arm and the take-off foot leads to a loss of overall rhythm in the movement, reducing the efficiency of mechanical force transfer from the ground to the arm, and subsequently decreasing serve accuracy.

7. The results confirm that the preparatory phase of the float serve requires a precise temporal balance between the moment of take-off and the onset of arm acceleration, which distinguishes highly accurate players from others.

8. Players with superior neuromuscular coordination demonstrated more accurate float serves due to the harmonious sequencing of body segments (foot – trunk – arm) within an integrated mechanical flow.

9. Improving biomechanical variables (angular and peripheral velocities) can serve as an effective indicator for evaluating skill performance levels, making them valuable diagnostic tools in specialized training programs for junior volleyball players.

10. The study confirms that successful float serving relies on the integration between temporal rhythm and mechanical precision, rather than on force or speed in isolation from the overall movement harmony.

Recommendations

Based on the conclusions of this study, the researcher recommends the following:

1. Implementing specialized training drills designed to develop motor synchronization between the striking arm and the take-off foot, using training methods that emphasize timing and temporal accuracy.
2. Focusing in training on the stages of generating angular velocity and transmitting it through the kinetic chain—from the foot, through the trunk, and to the striking arm.
3. Utilizing biomechanical video analysis to evaluate players' performance and identify temporal discrepancies between foot and arm movements during the serve.
4. Designing training units that develop angular and peripheral velocities progressively, enabling smooth kinetic force transfer and achieving optimal float serve accuracy.
5. Strengthening the muscles involved in take-off and striking arm actions to improve the efficiency of transmitting ground reaction forces, with emphasis on maintaining optimal body balance during execution.
6. Integrating neuromuscular coordination concepts into specialized volleyball training programs to enhance temporal harmony among the essential movement components.
7. Employing angular and peripheral velocity measurements as quantitative indicators to assess skill performance and monitor players' development throughout the preparatory stage.
8. Encouraging coaches to combine biomechanical training methods with technical skill work to enhance performance quality and float serve accuracy.



9. Conducting future studies addressing similar biomechanical variables in relation to the accuracy of other volleyball skills such as spiking or blocking, to expand the applied knowledge base in training science.
10. Developing specialized youth training programs that consider age-related progression and neuromuscular development in accordance with the demands of volleyball-specific skills.

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