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Biokinematic Analysis of Specific Variables of the Overhead Smash Skill and Its Correlation to Performance Accuracy in Tennis

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Abstract. Around the world, a few nations have begun to use organized planning. They are utilizing applied sciences to enhance performance levels in various sports. Meanwhile, competition among these nations has intensified to innovate modern scientific methods. Additionally, there is a focus on conducting studies and research, as well as addressing the fundamental factors involved in executing skillful performances to discover new training methods. Furthermore, attention is being given to the physical and psychological aspects specific to each sport, along with mechanical factors. This development has led to rapid advancements, significantly contributing to the evolution of different sports. All human and scientific disciplines are utilized in this development, including biomechanics, which employs kinematic analysis to perform a variety of tasks, for instance: (analysis, clarification, reasoning, improvement, findings, suggestions, and technique development). Consequently, this is regarded as one of the core biomechanical techniques. The process allows for the breakdown of a movement into its constituent parts according to the chosen categorization type. It then determines the characteristics of each component so that the appropriate mechanical laws and principles can be applied for the movement's optimal execution. The aim of the study is to establish a correlation between the values of certain biomechanical characteristics related to the overhead press skill and tennis performance accuracy. The researcher employed a descriptive methodology, with a sample consisting of three players from the youth category. Additionally, the researcher used scientific technical observation, measurement, analysis, and testing as means to collect data on certain biomechanical variables. To achieve scientific technical observation, video recording was utilized. The researcher concluded that there is a difference in the values of the biomechanical variables related to the motor performance of the overhead press skill among the research sample and across different stages of the movement.

Keywords. Biomechanical variables, overhead press skill, tennis

1-1 Introduction

Numerous countries throughout the world have begun to develop new scientific techniques, for instance conducting research and studies, whereas additionally concentrating on the essential elements involved in doing skill performance. In addition to addressing the mechanical components and sport-specific physical and psychological issues, this seeks to identify modern training approaches.

These techniques have produced rapid developments that have significantly aided in the growth of several sports. All human and scientific fields have contributed to this evolution, including biomechanics, which employs kinematic analysis to perform a variety of functions, such as (analysis, clarification and justification, improvement, findings, suggestions, and technique creation) (Majeed, 1992).

This is regarded as one of the fundamental techniques in biomechanics, enabling the dissection of movement into its constituent parts based on the preferred segmentation. In order to apply the appropriate mechanical principles and rules for the optimal movement method, it is possible to ascertain the nature of each component of the movement.

The use of modern devices and advanced scientific tools, along with sophisticated technologies, has facilitated the task of researchers and trainers in testing a scientific mechanism characterized by precision and objectivity for measuring and evaluating the technical performance of sports skills. This is achieved through a detailed analysis of movement by comparing facts against specific standards (Hammad, 1998).

Because tennis has changed over time, researchers have been exploring strategies to diagnose and subsequently address concerns related to skill performance and achievement. To enhance these two areas through the creation of diverse educational and training programs, a significant amount of research and studies have focused on the physical and skill-related components. This approach aims to avoid concentrating solely on the mechanical aspects of performance requirements, particularly concerning the overhead smash, which is regarded as the game's most crucial skill. Consequently, it becomes clear how essential it is to conduct research on overhead smash skills in tennis to identify areas where players on the national youth tennis team lack proficiency and to investigate potential solutions.

1.2 The Research Problem:

As a result of the game's significant advancements and the high skill level of tennis players, obtaining points is becoming increasingly challenging, underscoring the importance of utilizing the overhead pushing technique. While hitting the ball and the trajectory it takes from its launch from the player's racket until it reaches the target is known as performance efficiency, it precedes these two processes (output and efficiency) and represents how effectively the overhead pressing technique is reflected in the accuracy of its performance and the power of launching the ball, which is the ultimate result of skill performance.

Biomechanics views sports technique as a complex interplay of dynamic and static motor actions based on the optimal use of the player's motor potential and abilities to solve a specific motor task (El-Din, 1994).

According to the researcher, modifying the ball's hitting rates results from mechanical efficiency and performance, which are represented by time, mass, force, the trajectory of the center of gravity of the body mass, and the degree to which these variables influence the determination of the best dynamic trajectory. The factors that impact the ball and determine its trajectory and launch speed depend on the type and distance of hitting, in addition to other external factors (Basir, 1998).

Thus, mechanical studies in sports, including tennis skills, have gained significant importance, as each sports event has a specific goal that the athlete aims to achieve. For a tennis player, the objective is to score points, which necessitates a strong ability to utilize physical attributes and precision, along with a high level of skill in performance. Tennis skills largely depend on excellent physical fitness, in addition to mastering skill execution and strategies.

In order to develop effective remedies, it was crucial to pause and analyze this occurrence. Investigating this topic and understanding the biomechanical factors influencing the accuracy and effectiveness of overhead pressing to identify appropriate solutions constitutes the research challenge.

1-3 Objective:

- To identify the relationship between the values of biomechanical variables of the overhead smash skill and performance accuracy in tennis.

1-4 Hypothesis:

There is a significant correlation between the values of certain biomechanical variables of the overhead smash skill and performance accuracy in tennis.

1-5 Felids:

1-5-1 Human Felid: Some players from the Iraqi national tennis team (youth category).

1-5-2 Temporal Felid: From March 3, 2023, to April 15, 2023.

1-5-3 Spatial Felid: Al-Sayd Sports Club courts (training center for the Tennis Federation).

2- Methodology and Field Procedures

2-1 Methods

The researcher employed a descriptive survey method due to its suitability and the nature of the research.

2-2 Samples

The research sample consisted of (5) players from the national youth team for the year 2023.

2-3 Data Collection Methods

The following methods were used to collect data:

1. Scientific technical observation.
2. Measurement.
3. Questionnaire.
4. Test of accuracy in the overhead smash skill.

2-3-1 Tools and Devices Used in the Research Experiment

- ❖ A scale for measuring the mass of the players.
- ❖ A stadiometer for measuring the heights of the players.
- ❖ A measuring tape for measuring body parts of the players.
- ❖ Two video cameras (Sony Digital).
- ❖ Two external hard drives (one terabyte).
- ❖ Sixty tennis balls.
- ❖ A Dell core 7 computer with its accessories.
- ❖ A Canon laser printer.
- ❖ A special engineering ruler for drawing curves.
- ❖ Adhesive fluorescent markers for body joints.

2-3-2 Scientific Technical Observation

To achieve the scientific technical observation, the researcher used video recording, employing two Sony Digital video cameras manufactured in Japan. The first camera was positioned at a distance of 7.25 meters from the player and at a height of 1.07 meters above the ground. This setup was intended to identify the values of the biomechanical variables specific to the players.

Meanwhile, the second camera was placed 19.60 meters away from the player and at a height of 1.30 meters above the ground. This arrangement aimed to determine the values of the variables related to the ball. The recording speed of both video cameras was set to 25 frames per second. Figure (1) illustrates the location of the two cameras and the scale used.

2-3-3 Measurement

2-3-3-1 Player Mass

The mass of the players was measured using a medical scale that measures to the nearest (50 g).

2-3-3-2 Player Heights

A stadiometer was used to measure the heights of the players.

A measuring tape was used to measure the body parts of the players.

2-3-4 Questionnaire

A questionnaire form was prepared to identify the biomechanical variables related to the phases of the overhead smash skill. Additionally, a specific questionnaire form was prepared to select the appropriate test for the overhead smash skill.

2-3-5 Overhead Smash Skill Test

Test Name: Overhead Smash Skill Test (Al-Maamari, Al-Jawady, Qasim, Al-Sumaidaie, & Ghanem, 2006).

Test Objective: To measure the overhead smash strike.

Tools Used: A tennis court is divided as follows:

- A line is drawn along the length of the singles sideline, 3 feet inside the court, with a width of 2 inches, one line on the right side and one line on the left side.
- The back area is divided into two equal zones with a line parallel to the baseline, which can be labeled as A, B, C, D for brevity, as shown in the test diagram.

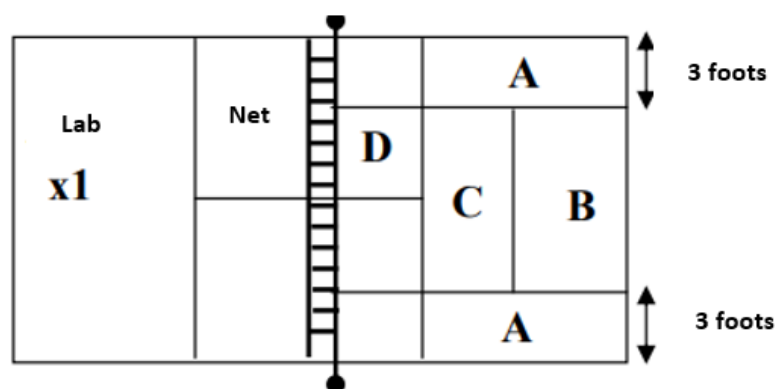


Figure 1

Illustrates the division of test areas for overhead serves in tennis

Test Instructions:

- The tester stands in the middle of the backcourt, holding a racket and in a ready position.
- The teacher stands on the opposite court near a basket of balls, also holding a racket.
- The assistant stands on the opposite court near the singles sideline.
- It is customary for the teacher to have an assistant to retrieve the balls.
- The tester may be given two warm-up attempts, which do not count.

- The tester is awarded 10 attempts.

Performance Method: The coach plays an elevated (arc) ball to the half of the court opposite the tester's standing position. The tester moves to take the appropriate ready stance, and when the ball drops to the ground and bounces back up, the tester performs an overhead smash to the opposite half of the court, attempting to land the balls in the highest scoring areas. (The serve is repeated if the teacher feels that the tester was not given a fair chance to hit the ball.)

Scoring System:

- Balls that fall outside the singles court or do not cross the net receive zero points.
 - Balls that fall in Area D receive one point.
 - Balls that fall in Area C receive two points.
 - Balls that fall in Area B receive three points.
 - Balls that fall in Area A receive four points.
 - Valid balls that land on the line receive the higher score for the designated area of that line.
- The final score for the test is the total of the points obtained from the ten attempts (the total score for the test is 40 points).

2-3-5 Research Variables Test.

2-3-6 Selection of Biomechanical Variables

The biomechanical variables for the research were selected through the presentation of a questionnaire to experts and specialists in the field of biomechanics and tennis. After collecting the questionnaires, the final form of the kinematic variables for the research was determined as follows:

1. Last approach phase (Hay, 1986).

1. Step length (cm)
2. Step time (s)
3. Step speed (s/cm)

2. Push phase (Teodoriscu, 1991).

1. Hip of the pivot leg.
2. Trunk tilt angle.
3. Pivot angle.
4. Height (m.s.l).
5. Vertical distance (m.s.l).
6. Time.
7. Angular speed of the throwing arm.

3. Flight phase (John, 1979).

1. Trunk tilt angle.
2. Flight.
3. Height (m.s.l).
4. Horizontal distance (m.s.l).
5. Vertical distance (m.s.l).
6. Time to reach maximum height (m.s.l).
7. Time to reach maximum height.

4. Ball variables (Najah Mahdi Shalash, 1988).

1. Ball height at the moment of launch.
2. Launch angle of the ball.
3. Ball speed.

2-7 The Pilot Experiment.

The pilot experiment was conducted on March 3, 2023, at 3:00 PM at the Al-Said Club (the training center for the Iraqi Tennis Federation). The objectives of the experiment were to:

- Ensure the proper functioning of the equipment.
- Establish the distance and height of the cameras from the players.
- Calculate the total duration of the experiment.
- Identify the number and efficiency of the working team.
- Verify the lighting conditions in the filming area.
- Recognize potential issues that may arise during the execution of the experiment.

3-8 The Final Experiment.

The final experiment was conducted on March 8, 2023, at 3:00 PM at the Al-Said Sports Club / training center for the Tennis Federation.

3-9 Data Extraction Method

After recording the players' attempts using two (Sony Digital video cameras), the cameras were directly connected to a computer. This was done to transfer these attempts and subsequently store them on the hard disk. Additionally, the Xing software was used to cut the attempts into frames, which were also stored on the hard disk. After that, the composite center of gravity for the player and the ball was extracted using (Excel 97) (Al-Sumaidaie, 1987).

After identifying the location and value of the composite center of gravitational attraction for the players, the coordinates of the x-axis and y-axis were obtained using (Adobe Photoshop PS). Based on the coordinates from the pixel calculator, the screen points (Pixel) were calculated.

Once the coordinates were determined, these data were entered into Excel 97 to convert them into actual values in centimeters by multiplying them by the real scale value of 1 meter. The vertical value appeared as 75 points and the horizontal value as 65 points due to the difference in the number of horizontal and vertical screen points. For the second camera's scale related to the ball's variables, the metric scale value for both the right and left sides (from the nine-meter line to the goal line) was 27 vertical points and 24 horizontal points, while the average metric scale was 28 vertical points and 26 horizontal points.

The values of the angles of joints and body parts were identified using AutoCAD by pointing to the first side of the joint angle to be measured and then pointing to the second side of the joint angle, which directly displayed the value of this angle. To determine the timing of the compression movement phases from above the head, the (Timer) program was used to calculate the times (Al-Hashemi, 1999).

To understand the shape of the motion path of the composite center of gravitational attraction, Excel 97 was utilized. Finally, the Photo Grid-Collage Maker program was used to arrange the cut images to identify the sequential motion images for each player, which were printed using a Canon laser printer.

Linear speed and angular speed were calculated according to the following equations (Hassanein, 1979):

$$\text{Linear speed} = \frac{\text{Displacement}}{\text{Time}}$$

$$\text{Angular velocity} = \frac{\text{Angular change}}{\text{Time}}$$

3-10 Statistical Treatments

The data were statistically analyzed using the (S.P.S.S) program, through which the values of the simple correlation coefficient (Pearson), the mean, and the standard deviation of the research variables were calculated (Alawi & Radwan, 2000).

4- Presentation, Analysis, and Discussion of Research Results

The following presents the results obtained by the researcher in light of his objectives and hypotheses, along with a scientific discussion of these results based on the theoretical framework and previous studies.

4-1 Presentation and Discussion of the Final Approach Step Results for the Research Sample

Table (1)

Shows the length, time, and speed of the final approach step, along with their means and standard deviations

Research Sample Variables	First Player	Second Player	Third Player	Fourth player	Fifth Player	Arithmetic mean	Standard deviation
Step length (cm)	85.00	100.00	95.00	100.00	94.00	94.80	6.14
Step time (s)	0.288	0.355	0.405	0.318	0.315	0.336	0.044
Step speed (cm/s)	295.13	281.69	234.56	314.46	298.41	284.90	30.45

It is evident from Table (1) that there is a difference in the length of the final approach step among the research sample, with the mean length being (94.8 cm) and a standard deviation of (6.14 cm). There is also a difference in the time of the step among the individuals in the research sample, with the mean time for the step being (0.336 seconds) and a standard deviation of (0.044 seconds). As for the results of the speed of the step among the individuals in the research sample, the mean speed was (284.9 cm/second) with a standard deviation of (30.45 cm/second).

The researcher attributes the difference in the time of the step to the length of the step; longer or shorter steps lead to longer or shorter times. This is one of the reasons for the variation in time among the individuals in the research sample.

Regarding the difference in the speed of the step among the individuals in the research sample, the researcher attributes this to either the variation in step length or the variation in step time,

as anything that causes a change in step length will lead to either a decrease or increase in speed (Hammad, 1998).

Additionally, it is confirmed that speed can be increased by increasing step length while keeping time constant, and vice versa. This is what occurred among the individuals in the research sample (Hassan & Al-Anbaki, 1988).

As indicated in Table (2), the correlation coefficient between step length, step duration, and step speed in the research sample and performance accuracy was computed at a significance level of 0.05.

$$\text{speed} = \frac{\text{Displacement}}{\text{Time}} \quad \text{Hochmuth(1988)}$$

The correlation coefficient value of 0.24 and the P-value of 0.969, both of which are higher than the significance level, indicate a weak relationship between step time and performance accuracy. Meanwhile, the correlation coefficient value of 0.156 and the P-value of 0.805 indicate a weak relationship between step speed and performance accuracy.

4.2 Presentation and Discussion of the Results of Some Biokinematic Variables on the Research Sample for the Payment Stage

Table 2

Shows the values of some angles of the body joints and some kinematic variables of the thrust phase, along with their calculated averages and standard deviations

Variables	Step length	Step time	Step speed	Aiming accuracy
Step length	1.000			
Step time	0.455 0.441	1.000		
Step speed	0.021 0.805	0.879 - 0.050	1.000	
Accuracy of performance	0.327 0.571	0.24 0.969	0.156 0.805	1.000

Table 2 indicates that there is a difference in the values of the variables, where the hip angle of the fulcrum man was 152.168, with a deflection of 36.418; the torso angle was 82.926, with a deflection of 9.198; the angle of the rear fulcrum man was 84.94, with a deflection of 3.761. The height of the center of gravity of the composite body reached an arithmetic mean of 128.79 cm, with a standard deviation of 10.60. The horizontal and vertical distances traversed by the center of gravity of the composite body reached arithmetic means of 46.46 cm and 42.23 cm, respectively, with standard deviations of 7.79 and 7.95.

The complete absence of the rising man at the moment of departure affects the diameter of the force torque. Additionally, the values of the rear pivot angle reached an arithmetic mean of 84.94, with a standard deviation of 3.76. This angle plays an important role in achieving the best height, and Ali confirms that both small and large angles of rise affect the level of performance (Al-Khafaji, 1984).

Also, during the Phase time, the arithmetic mean (0.1599) and the standard deviation (0.018) were obtained. To identify the relationship between these variables and the accuracy of performance, the correlation coefficient for these variables was calculated, and Table 3 shows this.

Table 3
 Illustrates the values of the correlation coefficient between the kinematic variables and the accuracy of performance during the payment phase

Variables	Hip (Fulcrum leg)	The Trunk		Height	Horizontal distance	Vertical distance	Time	Aiming accuracy
Fulcrum leg hip	1.000							
	0							
The Trunk	0.980	1.000						
	0.004	0						
Aviation	0.311-	-	1.000					
	0.611	0.122	0					
Altitude MTC	0.193-	-	-	1.000				
	0.755	0.357	0.562	0				
Horizontal distance	0.257	0.065	-	0.839	1.000			
	0.676	0.917	0.850	0.076	0			
Vertical distance	0.076-	-	-	0.926	0.811	1.000		
	0.903	0.213	0.401	0.024	0.096	0		
Time	0.164-	-	-	0.979	0.877	0.850	1.000	
	0.792	0.346	0.701	0.004	0.051	0.068	0	
Accuracy of performance	0.488-	-	0.312	-	0.576-	0.601-	-	1.000
	0.404	0.407	0.609	0.585	0.309	0.284	0.528	0

Table 5 indicates that the angle of the hip joint of the fulcrum man had a significant relationship with the angle of the trunk, with a correlation coefficient value of 0.98. In contrast, its relationship with the other variables was weak, and the relationship between the angle of the thighs and the remaining variables was also weak, as was the relationship of the angle of the rear fulcrum with the other variables.

Regarding the height of the center of gravity of the composite body, it showed a significant correlation with the vertical distance of the center of gravity of the composite body, with a correlation coefficient value of 0.926. This is evident, as it also had a strong correlation with the Phase time, where the correlation coefficient reached 0.979; the greater the vertical distance, the more time is required. However, the relationship with the remaining variables was weak (Othman, 1987).

4-3 Presentation and discussion of the results of some Biokinematic variables in the research sample for the flight phase

Table (4)

Presents the values of some angles of the body joints and certain kinematic variables of the flight phase, along with their average calculations and standard deviations

corner Player	Hip (pivot leg) (Degree)	torso (Degree)	Aviation (Degree)	Altitude MTC (Sam)	Horizontal distance (Sam)	Vertical distance (Sam)	Maximum height latency (s)
The first	137.26	101.73	23.86	156	63.08	50.67	0.2464
Second	145.11	82.40	19.50	164	73.85	36	0.2592
Third	155.53	87.02	30.43	166.67	35.38	21.34	0.2363
Fourth	137.81	91.76	30.10	164	61.54	38.67	0.2726
V	170.42	81.70	32.40	144	58.46	28	0.2247
s	149.226	88.922	27.258	158.934	58.462	34.936	0.2478
±on	13.95	8.222	5.392	9.257	14.145	11.13	0.0187

Table (4) indicates that there is a difference in the measurement of variables in the values of the angle of the hip joint of the fulcrum man, with an arithmetic mean of (149.226 cm) and a standard deviation of (13.95). For the angle of the trunk joint, the arithmetic mean is (88.92 cm) with a standard deviation of (8.222). In the angle of flight, the arithmetic mean is (27.25 cm) and the standard deviation is (5.392). The height of the center of gravity of the body has an arithmetic mean of (158.934 cm) and a standard deviation of (9.25). The horizontal and vertical distances of the center of gravity of the composite body have arithmetic means of (58.46 cm) and (34.93 cm), with standard deviations of (14.145) and (11.13), respectively. There was a convergence among the research sample at the time of reaching the highest altitude, with an arithmetic mean of (0.2478 cm) and a standard deviation of (0.0187).

To identify the relationship between these variables and the accuracy of performance, the correlation coefficient between them was calculated, as shown in Table (5).

Table (5)

Shows the values of the correlation coefficient between the kinematic variables and the accuracy of the performance of the flight phase

Variables	Hip (pivot leg)	torso	Aviation	Altitude MTC	Horizontal distance	Vertical distance	Maximum latency	Aiming accuracy
Hip leg (Pivot)	1.000							
	0							
torso	0.728	1.000						
	0.163	0						
Aviation	0.198 -	-	1.000					
	0.750	0.800	0					
	0.409 -	0.121	0.336 -	1.000				

Altitude MTC	0.494	0.846	0.580	0				
Horizontal distance	0.072	0.025	0.654 -	0.188 -	1.000			
	0.909	0.969	0.231	0.762	0			
Vertical distance	0.621	0.768	0.541 -	0.057 -	0.658	1.000		
	0.263	0.129	0.346	0.928	0.227	0		
Maximum latency	0.339 -	0.270	0.416 -	0.637	0.480	0.477	1.000	
	0.576	0.661	0.487	0.247	0.413	0.416	0	
Accuracy of performance	0.262 -	-	0.221 -	0.487 -	0.496	0.241 -	0.286 -	1.000
	0.670	0.763	0.720	0.406	0.395	0.696	0.641	0

Table (6) makes it abundantly evident that the coordination of the body parts' work, the mastery of movement transfer, and the gradation of movement of parts and joints in terms of their external appearance are all necessary for the accuracy of sports movements and the mastery of the art of performing these movements. As demonstrated by the motor transfer from the trunk to the arms and vice versa, as well as from the trunk to the legs and vice versa, we can observe that the primary forms of motor transport are from the trunk to the organs and vice versa.

The motor alignment of the motions of various body parts during the motor course of the sports talent allows one to view the external phenomena known as the beauty of movement.

To ensure optimal performance, it is essential to plan movements that facilitate the achievement of the goal with the least amount of effort. This is accomplished by striking a balance between the player's motor potential and the motor compatibility of the sports movements used to perform the motor task. When the movement is executed within this framework, it becomes unique, and the performance becomes agile; when it is not, it results in subpar performance (Basir, 1998).

Several of these joints move in multiple ways during pressing motions. The pelvis twists around its axis when the front foot's heel touches the floor, followed by the trunk moving as the second link, the shoulder girdle moving through the sternocleidomastoid joint, the arm rounding, and the arm rotating around the shoulder joint's longitudinal axis while the elbow joint moves in the wrist joint's transverse axis (El-Din T. H., 1993)

In this regard, Hochmuth mentions that every movement of a single loop in the chain or single loops does not involve only the muscle groups surrounding the joints of that specific part, but also engages other muscles. To enable body parts to move and perform rapid, powerful, and controlled movements, it is essential for the other parts to provide support that maintains stability. This means that the muscle groups in other parts of the body must exert a static influence. As the number of loops increases, it becomes necessary for the static tension of those muscle groups affecting the pivot to also increase. It should be noted here that these connections indicate that this static tension leads to rapid fatigue.

"For these reasons, it is correct to say that 'all parts of the body participate in every movement.' The more there is harmony in each part of the body performing its function alongside the other parts during these movements, the more complete and precise these movements can be (Hochmuth, 1988).

4-4 Ball Variables

Table (6)

Shows the values of some variables related to the ball, their means, and standard deviations

Variables Players	Ball height at starting point (cm)	Ball starting angle (Degree)	speed Ball (m/s)
The first	291	7-	20.69
Second	274	10-	17.99
Third	293	8-	18.35
Fourth	272	11-	17.96
V	285	9-	18.38
Arithmetic mean	283	9-	18.67
Standard deviation	9.61	1.58	1.14

It is evident from Table (6) that there is a variation in the ball's height at the moment of launch, the launch angle, and the ball's speed.

To understand the relationship between the ball variables and their correlation with shooting accuracy, the correlation coefficient between these variables was calculated, and Table (6) illustrates this.

Table (7)

Shows the correlation values between the variables related to the ball and shooting accuracy

Variables	Ball height at the moment of departure	Ball starting angle	Ball speed	Aiming accuracy
Ball starting angle	0.937 0.019			
Ball speed	0.309 0.546	0.625- 0.26		
Accuracy of performance	0.332- 0.585	0.289 0.638	0.234- 0.705	

Table (7) indicates that there is a significant relationship between the height of the ball at the moment of launch and the launch angle, with a correlation coefficient of (0.937). This is because when the launch angle changes towards a fixed target, it consequently leads to a change in the launch height of the object.

On the other hand, the relationship between the height of the ball at the moment of launch and the speed of the ball was weak, as well as the relationship between height and performance accuracy, which was also weak.

5- Conclusions and Recommendations:

5-1 Conclusions:

In light of the results obtained through data analysis and statistical treatments conducted by the researcher, based on the facts that emerged from the experiment, the following was revealed:

- ❖ There is a difference in the values of the biomechanical variables of motor performance for the overhead smash skill in tennis among the research sample and across different phases of movement.
- ❖ An increase in the duration of the final approach step negatively affects step speed, which in turn impacts the transfer of the body's center of gravity in the absorption phase, thereby affecting the thrust process.
- ❖ The horizontal distance traveled by the body's center of gravity was greater than the vertical distance during the flight phase, with the mean of the horizontal distance being (58.462 cm) and the vertical distance (34.936 cm).
- ❖ There is a flexion in the trunk joint during the thrust phase, which hinders its effectiveness in propelling the body's center of gravity upward, with the mean angle of the trunk joint for the research sample being (82.92).
- ❖ The relationship between the biomechanical variables of the overhead smash skill for the research sample was mostly weak, reflecting poor performance due to a lack of coordination among the body's segments.

5-2 Recommendations:

In light of the conclusions drawn, the researcher recommends the following:

- ❖ Emphasize the process of pushing the center of mass of the body to ensure it is directed vertically.
- ❖ Focus on the horizontal speed during the final approach step by reducing the step time to gain significant horizontal speed for the center of mass in the direction of movement, which aids in propelling the body upwards.
- ❖ Highlight the extension of the trunk joint upwards during the push phase for its effectiveness in movement.
- ❖ Prioritize training on the technical performance of the overhead smash skill and improve the performance of body parts.
- ❖ Conduct similar studies on the Iraqi national team and address issues that have not been previously discussed.

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