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The Effect of Selected Kinematic Variables on the Accuracy of Topspin Forehand among Table Tennis Players

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Abstract This study aimed to identify the effect of selected kinematic variables on the accuracy of the topspin forehand among table tennis players. The study sample consisted of (8) male players who play in the Jordanian First Division Table Tennis League; (age= 23.74 ± 1.72 years, mass=71.22 ± 11.21 kg, height=1.74 ± 0.10 m). The study used A (Canon EOS 80D) camera, which has a speed of (500) images per second, and Kinovea (0.8.15) program was used to analyze the movements. The shooting accuracy test was also used to reach the accuracy of Forehand Topspin shooting. The results of the statistical analysis confirmed the acceptance of the main hypothesis of the study, which states that there is a statistically significant impact of the selected kinematic variables on the accuracy of the topspin forehand at ($\alpha \leq 0.05$). The results also showed the acceptance of three sub-hypotheses, which state that there is a statistically significant impact at ($\alpha \leq 0.05$) of shoulder's angular velocity, wrist angle and racket's horizontal velocity on the accuracy of the topspin forehand. In light of the results, the study recommended the necessity of urging table tennis coaches in the Jordanian league to develop an appropriate mechanical kinematic model for each player when performing the skill of the forehand topspin.

Keywords Kinematic, Sports Training, Topspin Forehand, Table Tennis

1. Introduction

The sport of table tennis is considered as one of the most popular and important racket sports in the world. It is estimated that there are about (38453) table tennis players in 2022 [9]. Topspin forehand is considered as the most common stroke in table tennis [3].

Topspin forehand is also viewed as the most effective stroke; it is a complex skill, and multi-joint movement performed in proximal to distal sequences, where several muscles work in different phases and different ways within a coordinated kinematic series [1].

Spin and speed are two main elements that have an important role in the game of table tennis, where helps increase the development of table tennis techniques at the international level. Eventhough there is a lot of information about ball spin based on qualitative analyses, there is still a need to conduct further qualitative studies to come up with more information about the topic [10].

Topspin forehand is an effective offensive stroke, particularly against backspin balls. Researchers in this domain suggested that both coaches and players should compare the kinematics of the stroke between players with different performance levels and between different ball spins [4].

Almost all table tennis players consider topspin forehand shot as one of the most important offensive shots in table tennis, since it is characterized by high speed and fast rotation of the ball. Also, it is the most frequently-used shot in top-level matches in table tennis [5].

Biomechanical principles are the primary sources of the knowledge used in the qualitative analysis of sports. It is one of the most important professional activities of teachers and coaches to concentrate on how qualitative analysis is made of the motor skills to help athletes improve their performance

The biomechanical principles are regarded as the main resources of the knowledge that is employed in sports qualitative analysis. Coaches should focus on how qualitative analysis is made based on motor skills which, in turn, helps athletes improve their performance [10].

The kinematic analysis for the stroke of table-tennis topspin forehand has investigated many different variables, such as joint angular speeds, ball accuracy as well as others [6].

Radial deflection, inward rotation of the arm and flexion of the palms as well as arm abduction result in the correct vertical trajectory for the racket. Also, the angles and speeds of the arm joints provide the racket with the required momentum to hit the ball correctly and give it the appropriate spin [2].

Determining the actual kinematic variables that affect the accuracy of the forehand topspin shot in the game of table tennis, such as the angles of joints, the throwing angle, the angular velocities of joints, the racket speed, the kinetics of the racket when the ball is hit, in addition to the time needed to accelerate the racket are amongst the main factors on which the skill performance level of table-tennis players depends when shooting a forehand topspin [4].

Therefore, this study aimed to identify the effect of some kinematic variables on the accuracy of the topspin forehand throw at the moment of shooting the ball.

Based on the above-mentioned, the researcher introduced the following hypothesis: "there is a statistically significant impact for the selected kinematic variables on the accuracy of the topspin forehand at ($\alpha \leq 0.05$)".

2. Methods

Participants

The study data were collected from (8) male players who play in the Jordanian First Division Table Tennis League; (age= 23.74 ± 1.72 years, mass=71.22 ± 11.21 kg, height=1.74 ±0.10 m). All the players play using their right hand and their average experience ranges from (3 to 4) years, where they have previously represented the Jordanian national teams in table tennis.

The field study test

After the player performs the appropriate warm-up and takes the position of readiness to receive the ball, the ball is directed to him through the ball thrower, and he returns it by using the topspin forehand strike towards the opponent’s table, which is divided into (5) zones. Zone (1) is given (1) point, Zone (2) is given (2) points, Zone (3) is given (3) points, Zone (4) is given (4) points and Zone (5) is given (5) points, as shown in figure (1) below. Each player is given (5) attempts.

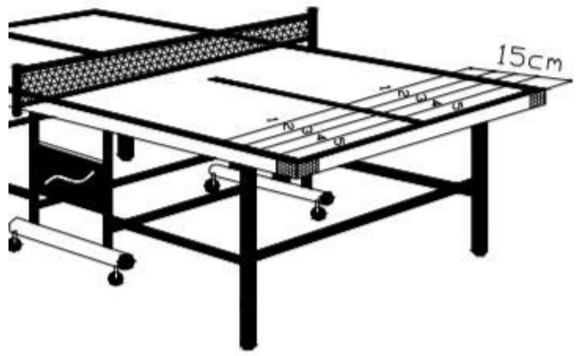

Figure 1. Division of the five test zones

Data-collection method

The researcher used (Canon EOS 80D) camera, which has a speed of (500) images per second, and (Kinovea 0.8.15) software was used to analyze the movements. The camera was placed in a position that is perpendicular to the player's body and on the axis of the side performance from the right side. All the attempts were filmed using video cameras, and then the videos were analyzed using (Kinovea 0.8.15) software.

The study hypotheses

The main hypothesis

$H_0$1: There is a statistically significant impact of the selected kinematic variables on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The related sub-hypotheses

$H_0$1-2: There is a statistically significant impact of trunk angle on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

$H_0$1-3: There is a statistically significant impact of shoulder angle on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

$H_0$1-4: There is a statistically significant impact of Shoulder’s angular velocity on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

$H_0$1-5: There is a statistically significant impact of elbow angle on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

$H_0$1-6: There is a statistically significant impact of wrist angle on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

$H_0$1-7: There is a statistically significant impact of elbow’s angular velocity on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

$H_0$1-8: There is a statistically significant impact of wrist's angular velocity on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

$H_0$1-9: There is a statistically significant impact of racket's horizontal velocity on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

$H_0$1-10: There is a statistically significant impact of racket's vertical velocity on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The Statistical Analysis

The researcher used the following statistical methods:

- Mean and standard deviation for the descriptive statistics of the study variables.
- Normality indicators (Skewness – Kurtosis) to describe how close are the data distributions of the research's variables to the theoretical normal distribution.
- (VIF) variance inflation factor in order to check for multi-collinearity.
- R2 to investigate the model fit.
- ANOVA f-ratio to determine the ratio between the mean squares of the regression predicted values and the mean square of the residuals. This test is an inferential one; based on it, we can decide the acceptance or rejection of the research hypothesis.
- Coefficients (β) and (Sig (t)) in order to verify the extent to which there is a statistical relationship between the independent variables (the kinematic variables) and the dependent variable (forehand topspin accuracy) as well as the type of this relationship.

In order to apply the linear regression and test the research hypothesis, two basic assumptions concerning the application of multiple linear regression should be checked; the normality of the distribution of the variables data and the level of multi co-linearity between the independent variables (predictors).

The results

The distribution of normality data was described using skewness and kurtosis, whereas the multi co-linearity was estimated by using the (variance inflation factor) VIF tests. Table (1) shows the results:

Table 1. The descriptive statistics for study variables

Variables	Min	Max	Mean	Std. Deviation
THA (°)	23.77	25.87	24.35	0.58
TA (°)	103.02	105.50	104.54	0.75
SHA (°)	23.09	25.10	24.02	0.62
SHAV(°/S)	33.25	37.80	34.67	1.11
EA(°)	69.22	72.22	70.69	0.72
WA(°)	227.10	232.20	229.91	1.15
EAV(°/S)	178.90	181.20	179.73	0.63
WAV(°/S)	70.23	73.85	71.49	0.98
RHV (CM/S)	51.00	53.54	52.06	0.77
RVV(CM/S)	116.10	117.88	116.84	0.58
Accuracy	20.00	25.00	22.50	1.53

Abbreviations: THA- Throw Angle, TA- Trunk Angle, SHA- Shoulder Angle, SHAV- Shoulder's Angular Velocity, EA- Elbow Angle, WA- Wrist angle, EAV-Elbow's Angular Velocity, WAV-Wrist's Angular Velocity, RHV- Racket's Horizontal Velocity, RVV-Racket's Vertical Velocity.

Table (1) showed the min, max, mean and standard deviation values for the kinematic variables and accuracy. Accuracy ranged between (20) and (25) with a mean value of (22.50 or 23 approximately).

Table 2. Normality indicator and the VIF test for multi collinearity

Variables		Normality indicators		Multi collinearity
		Skewness	Kurtosis	VIF
Independent variables	THA (°)	1.04	0.21	3.00
	TA(°)	-0.57	-0.81	2.43
	SHA (°)	0.01	-0.82	1.51
	SHAV (°/S)	1.28	1.35	3.07
	EA (°)	0.33	-0.12	1.91
	WA(°)	-0.17	0.78	2.50
	EAV (°/S)	0.57	-0.34	1.51
	WAV (°/S)	0.64	0.00	1.38
	RHV (CM/S)	0.25	-0.79	1.36
	RVV (CM/S)	0.29	-1.30	2.32
Dependent variable	Accuracy	0.17	-0.58	-

Table (2) showed the skewness kurtosis values. These two indicators describe how close the data distributions of the study variables to the theoretical normal distribution. The values of the indicators are considered to be close to the normal distribution if they range between (-3 and +3) for both indicators. The mentioned values revealed a data distribution that is close to the normal distribution.

The results of VIF (Variance Inflation Factor) illustrated in the previous table showed that the greatest reported value was (3.07) for the SHAV (°). However, this value was less than the maximum reference value (10), which expresses low collinearity (i.e. low correlation between the independent variables).

Table (3) showed the results of multiple linear regression that are used to investigate the impact of the selected kinematic variables on the accuracy of the topspin forehand.

The determination coefficient (R^2) is considered as an important indicator to investigate the model fit. It represents the percentage of the variation observed in the dependent variable, which could be explained by the (predictors) independent variable. The more the value of (R^2), the better the model is, and the stronger explanation the independent variables will have to predict the dependent variable (maximum value is 1); ($R^{2)}$ was calculated to be (52.5% of the expressed a percentage) for this model.

Another important indicator for the model fit is the (f) ratio between the mean squares of the regression predicted values and the mean square of the residuals. As the mean squares of the residuals decrease, less error will be reported by the regression model; this is expressed by the larger (f) values. This test is considered as an inferential test, where we can decide the acceptance or rejection of the research hypothesis. The calculated (f-value) was (3.204), which is statistically significant, since the related significance value (0.007) was less than (0.05).

Therefore, the research hypothesis was accepted.

Table 3. Multiple linear regression for testing the impact of the selected kinematic variables on the accuracy of topspin forehand

Independent variables	Coefficient of determination			ANOVA results		Decision
	R	R2	Adj R2	f	sig	
THA (°)	0.**725**	0.**525**	**0.361**	**3.204**	**0.007**	Supported
TA (°)						
SHA (°)						
SHAV(°)						
EA(°)						
WA°)						
EAV(°)						
WAV(°)						
RHV (°)						
RVV(°)						

Table 4. The impact coefficients of the selected kinematic variables on the accuracy of topspin forehand

Sub hypothesis	Independent Variables	Coefficients					Decision
		B	SE	β	T	Sig(t)	
$H_0$1-1	THA (°)	-.215	.583	-.082	-.370	.714	Not supported
$H_0$1-2	TA (°)	.054	.409	.027	.133	.895	Not supported
$H_0$1-3	SHA (°)	.222	.389	.090	.570	.573	Not supported
$H_0$1-4	**SHAV**(deg/s)	.772	.309	.561	2.500	**.018**	Supported
$H_0$1-5	EA(°)	.367	.374	.174	.981	.335	Not supported
$H_0$1-6	**WA(°)**	-.657	.271	-.491	-2.427	**.022**	Supported
$H_0$1-7	EAV(deg/s)	-.677	.382	-.279	-1.773	.087	Not supported
$H_0$1-8	WAV(m/s)	-.357	.234	-.229	-1.521	.139	Not supported
$H_0$1-9	**RHV** (cm/s)	1.304	.298	.654	4.381	**.000**	Supported
$H_0$1-10	RVV(cm/s)	-.264	.516	-.100	-.512	.612	Not supported

As shown in table (4), the effect coefficients revealed that increasing the numerical value of some kinetic variables resulted in an increase in the accuracy of the forehand topspin shooting, which are: TA (0.027), SHA (0.090), SHAV (0.561), EA (0.174), and RHV (0.654).

The numerical increase of the other kinematic variables decreased the accuracy; this is shown by the negative sign of these variables in (β).

The results revealed that the variables of SHAV (sig = 0.018), WA (sig = 0.022) and RHV (sig = 0.000) showed a significant decrease as the significance value was less than (0.05), which means that these variables had a statistical impact on the accuracy of the forehand topspin shooting among table tennis players. The results also revealed that there are differences in the relationship between the value of these numerical variables and accuracy, since the accuracy increases with the increase in the numerical value to each of SHAV and RHV and decreases with the increase in the numerical value of (WA).

Testing the sub-hypotheses

$H_0$1-1: There is a statistically significant impact of THA on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for THA= (-0.082); this refers to a negative impact, which leads to a decrease in the accuracy of the forehand topspin strike. This value was not statistically significant, since the related significance value was (0.714), which is more than (0.05); suggesting the rejection of the alternative hypothesis.

$H_0$1-2: There is a statistically significant impact of TA on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for TA = (0.027). Indeed, this refers to a positive impact, which results in an increase in the accuracy of the forehand topspin strike. This value was not statistically significant, since the calculated significance value was (0.133), which is more than (0.05); indicating that the alternative hypothesis is rejected.

$H_0$1-3: There is a statistically significant impact of SHA on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for SHA= (0.090). This indicates a positive impact, which results in an increase in the accuracy of the forehand topspin strike. This value wasn't statistically significant as the calculated significance value was (0.570), which is more than (0.05); indicating that the alternative hypothesis is rejected.

$H_0$1-4: There is a statistically significant impact of SHAV on the accuracy of the topspin forehand at ($\alpha \leq$ 0.05).

The standardized impact value for SHAV = (0.561). This implies that there is a positive impact, which results in an increase in the accuracy of the forehand topspin strike. This value was statistically significant, since the significance value was (0.018) was, which is less than (0.05); indicating that the alternative hypothesis is accepted.

$H_0$1-5: There is a statistically significant impact of EA on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for the EA was (0.174). This refers to a positive impact, which results in an increase in the accuracy of the forehand topspin strike. This value was not statistically significant, since the related significance value (0.981) was more than (0.05); indicating that the alternative hypothesis is rejected.

$H_0$1-6: There is a statistically significant impact of WA on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for WA = (- 0.491). This indicates that there is a negative impact, which results in a decrease in the accuracy of the forehand topspin strike. This value was statistically significant, since the related significance value was (0.022), which is less than (0.05); indicating that the alternative hypothesis is as accepted.

$H_0$1-7: There is a statistically significant impact of EAV on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for EAV= (- 0.279). This shows that there is a negative impact, which results in a decrease in the accuracy of the forehand topspin strike. This value wasn't statistically significant, since the significance value was (0.087), which is more than (0.05); suggesting that the alternative hypothesis is rejected.

$H_0$1-8: There is a statistically significant impact of WAV on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for WAV= (- 0.229). This indicates that there is a negative impact, which results in a decrease in the accuracy of the forehand topspin strike. This value wasn't statistically significant, since the significance value (0.139) was more than (0.05); suggesting that the alternative hypothesis is rejected.

$H_0$1-9: There is a statistically significant impact of RHV on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for RHV= (0.654). This indicates that there is a positive impact, which results in an increase in the accuracy of the forehand topspin strike. This value was statistically significant, since the related significance value was (0.000), which is less than (0.05). Therefore, the alternative hypothesis (research hypothesis) is accepted.

$H_0$1-10: There is a statistically significant impact of RVV on the accuracy of the topspin forehand at ($\alpha \leq 0.05$).

The standardized impact value for the RVV= (- 0.100). This indicates that there is a negative impact, which results in a decrease in the accuracy of the forehand topspin strike. This value wasn't statistically significant as the related significance value was (0.612) which is more than (0.05). Therefore, the alternative hypothesis (research hypothesis) is rejected.

3. Discussion

The results showed that the main study hypothesis stating that "there is a statistically significant impact of the selected kinematic variables on the accuracy of the topspin forehand shot among table tennis players" is accepted. The study results also revealed the acceptance of the sub-hypotheses related to the variables of SHAV, WA and RHV, where the results revealed that there is an effect of these variables on the accuracy of the topspin shot among table tennis players, whereas the sub-hypotheses related to the rest of the variables were rejected and the alternative hypotheses were accepted, where they revealed that there was no effect for these variables on the accuracy of the topspin shot among table tennis players.

The existence of impact for all the kinematic variables suggested that the accuracy of the topspin among table tennis players is affected by the values of the kinematic variables; this also revealed that the kinematic variables addressed in this study are valid and related to the skill of topspin in table tennis. Several previous studies, such as [3] and [2] suggested that there is a relationship between the kinematic variables and the accuracy of the skill of topspin in table tennis.

The variable (SHAV) had a mean of (34.67 degrees / sec). In fact, the shoulder joint is the largest joint with regard to the arm's motor range; it is also the first joint carrying the racket in action. Therefore, the angular velocity affects this joint in determining the whole arm's speed of work, especially the circumferential velocity of the arm; accordingly, the racket is confirmed by the equation of the arm's circumferential velocity, which is equal to the shoulder's angular velocity. [1] confirmed this relationship, where the study showed that there is a statistically significant correlation between the angular velocity of the shoulder and the speed of the racket as well as the accuracy of topspin shooting in table tennis.

As for the variable of (WA), with a mean of (229.91 degrees), the results revealed that the wrist joint plays an important role in all the racket games, particularly table tennis. Indeed, the results showed that the direction of the racket’s movement and the velocity of the racket either vertically and horizontally depend on the movement of the wrist joint, which constitutes the final outcome of the body’s work. The kinematic momentum moves from the feet to the trunk, the shoulder, then the elbow, up to the wrist; therefore, the player’s mastery of the wrist joint's movement is considered as the final outcome of this motion. Through the wrist, the movement is transmitted to the racket and from it to the table tennis ball. The sensitivity of the wrist's function in the game of table tennis is emphasized by the small size of the ball and the table as well. [8] and [7] emphasized the importance of the wrist joint's function in determining the accuracy of the topspin forehand in table tennis.

As for the variable of RHV, [4] suggested that the racket horizontal velocity plays an important role in raising the performance level of the topspin forehand in table tennis, since the player, regardless his level, should do his effort to reach the racket at an appropriate velocity in order to perform a high-accuracy stroke. This was asserted by the results of this study, which revealed that the RHV, with a mean of (52.06 CM/S) had an important role in the accuracy of the topspin forehand. In this vein, it should be noted that the topspin forehand mechanism shows that the racket's horizontal movement speed is the last movement that the player performs before shooting the ball. Improper speed reduces the ball's torque and direction of movement which, in turn, reduces the effectiveness of the topspin forehand or may completely take the ball away from the table.

4. Conclusion

This study investigated the impact of selected kinematic variables on the accuracy of topspin forehand among table tennis players, where the results revealed that all of the selected kinematic variables, when taken together, affected the accuracy of the topspin forehand among table tennis players. When addressing each variable separately, the results revealed that the variables of SHAV, WA and RHV had a statistically significant effect on the accuracy of the topspin forehand among table tennis players.

Based on the results, the study recommended the necessity of urging table tennis coaches in the Jordanian First Division Table Tennis League to reach the appropriate mechanical kinematic model for each player when performing the skill of forehand topspin.

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