The diversity of movement patterns in the execution of a «Top spin» right-handed stroke in table tennis among elite athletes

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Abstract

Objective of the study was to investigating the fluctuations in the motion patterns of the «top spin» forehand stroke in table tennis among elite players.

Methods and structure of the study. Eight expert male table tennis players executed a «top spin» on the right side of the ball under standard circumstances, adjusting the speed and power to perfection, aiming to strike the ball in a specific area of the table. Each athlete attempted to execute the «top spin» at least five times.

The spatial and temporal motion parameters were recorded using the Qualisys hardware and software system. The Qualisys Track Manager software was employed to initially gather data from six high-speed ProReflex video cameras during the biomechanical analysis. The shooting frequency in the experiment was set at 200 Hz.

Results and conclusions. Based on the analysis of the trajectory and velocity of the racket, we determined the following kinematic parameters of the «top spin» forehand: - The maximum velocity of the racket. - The duration of each of the three selected phases of the «top spin» stroke. - The path of the racket during each of the three selected phases of the stroke.

The obtained kinematic parameters of the «top spin» forehand for eight tennis players, along with their average values and coefficients of variation, reflect the significant differences in technique among individuals. It is possible that tennis players employ distinct approaches to accelerate the striking arm when executing the top spin forehand.

Keywords: *table tennis, highly skilled male athletes, topspin right, kinematic characteristics of topspin, variability of speed parameters of movement.*

Introduction. The efficiency of the top spin stroke in table tennis may depend on the optimal value of a number of biomechanical characteristics. These characteristics may act as both criteria for the rationality of the technique and indicators reflecting the level of physical fitness of tennis players. In order to control the level of technical fitness of tennis players, it is necessary to have model characteristics of the technique, which may be specific values of the kinematic characteristics of the top spin stroke obtained with the help of modern biomechanical hardware and software systems for highly qualified athletes. It is necessary to understand that the spatial, temporal and spatial-temporal characteristics of the top spin stroke, even for highly qualified tennis players, may have a large variability [4, 6].

Currently, there are a small number of studies in the literature devoted to the study of the technique of the top spin stroke and its variability in highly qualified table tennis players using modern biomechanical hardware and software systems [4, 6].

Objective of the study was to investigating the fluctuations in the motion patterns of the «top spin» forehand stroke in table tennis among elite players.

Methods and structure of the study. To achieve this goal, we conducted a laboratory experiment on the basis of the laboratory of the Department of Biomechanics and UNM RUS (GTSOLIFK) using the three-dimensional shooting method. Eight male tennis players aged 22 to 27 years, whose height was 175-187 cm, weight 75-94 kg, took part in the experiment. All of them had the title of master of sports in table tennis.

During the experiment, each subject performed a «top spin» hit on the right side of the ball, which was thrown by one of the experimenters. The hit was performed under standard conditions with the installation of optimal speed and force of execution in order to hit the ball into a certain area of the table. Before the experiment, the subjects performed a warm-up and trial attempts of the technique being studied. For each subject, at least five attempts of the «top spin» hit were recorded during the experiment. During the execution of striking actions, we performed a three-dimensional biomechanical survey, which was carried out using the hardware and software complex «Qualisys». During the biomechanical survey, using the software «Qualisys Track Manager», primary data collection was performed from six high-speed video cameras «ProReflex». The synchronization system of these cameras allowed us to implement a three-dimensional case of shooting. The shooting frequency in the experiment was 200 Hz. The accuracy of measuring the change in the coordinates of the markers was determined by the error in calibrating the system, which did not exceed 1,6 mm along each of the three axes of space. To build a multi-link model of the athlete's body during the biomechanical survey, we marked the main reference points of the body of the subjects, as well as the conditional center of mass of the racket (Figure 1).

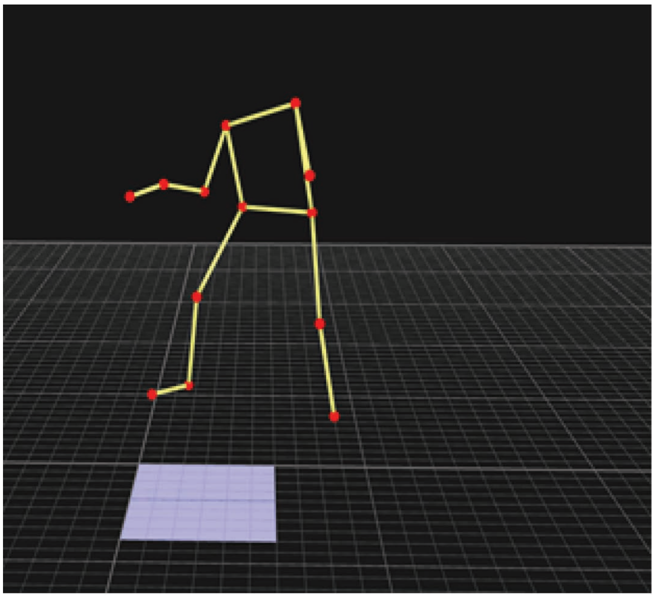

Figure 1. Construction of a tennis player's body model in three-dimensional space using the Qualisys Track Manager software after conducting a biomechanical survey

Results of the study and discussion. After conducting a laboratory experiment based on the analysis of the trajectory of the racket head movement and the graph of the change in racket speed, we determined the phase composition of the topspin strike from the right in table tennis based on the following reference moments of racket movement (Figure 2):

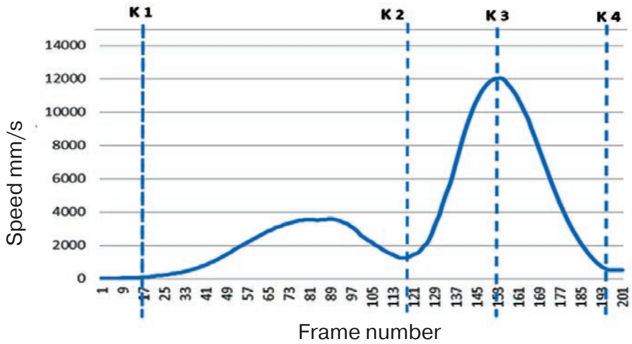

Figure 2. Change in racket speed and main supporting moments of movement when performing a topspin strike from the right

Note: K1 – the moment of the beginning of the movement; K2 – the moment of the end of the swing; K3 – the moment of reaching the maximum speed of the racket; K4 – the moment of stopping the movement of the racket.

Based on the fact that the moment of reaching the maximum speed of the racket (K3) corresponds to the moment of impact with the ball, we identified the following phases of the topspin stroke in table tennis:

1. The swing phase (from the moment K1 to the moment K2).
2. The acceleration phase of the racket (from the moment K2 to the moment K3)
3. The braking phase of the racket (from the moment K3 to the moment K4).

Based on the analysis of the trajectory and speed of the racket, we determined the following kinematic characteristics of the topspin stroke on the right:

- the maximum value of the racket speed;
- the execution time of each of the three identified phases of the topspin stroke;
- the path of the racket in each of the three identified phases of the impact action.

The obtained kinematic characteristics of the topspin stroke on the right for eight tennis players, as well as the average values and the coefficient of variation are presented in the table.

Kinematic characteristics of forehand topspin strokes of highly skilled table tennis players (n=8)

Test takers	Max. racket speed (m/s)	Time of execution of the swing phase (s)	Racket acceleration phase execution time (s)	Racket braking phase execution time (s)	Racket path during swing phase (mm)	Racket travel path during acceleration phase (mm)	Racket travel path during braking phase (mm)
D.E.	13,1	0,73	0,25	0,17	1259	1325	1142
N.E.	9,7	0,5	0,19	0,24	748	987	886
V.A.	11,3	0,6	0,23	0,2	1444	1463	1266
D.A.	15,9	0,43	0,13	0,17	1473	1385	1363
I.V.	15	0,5	0,15	0,15	1493	1379	1262
A.R.	16,9	0,52	0,22	0,15	1640	1550	1484
P.A.	12,4	0,53	0,22	0,2	1182	1230	1303
A.L.	15,3	0,61	0,2	0,18	1323	1194	1370
Average value	13,7	0,55	0,19	0,18	1320	1314	1259
Standard Deviation	2,4	0,09	0,04	0,03	272	175	180
Coef. variations, %	18	16	20	16	20	13	14

For all kinematic characteristics of the forehand topspin stroke obtained in the laboratory experiment, a large intra-group variability is observed, which is reflected in the value of the variation coefficient.

Thus, for the maximum racket speed, the average value for the group was 13,7 (±2,4) m/s, the variation coefficient was 18%. The time to complete the swing phase was 0,55 (±0,09) s, the coefficient of variation was 16%. The time to complete the acceleration phase was 0,19 (±0,04) s, the variation coefficient was 20%. The time to complete the braking phase was 0,18 (±0,03) s, the variation coefficient was 16%. The average racket travel distance in the swing phase for the group was 1320 (±272) mm, with a variation coefficient of 20%. The racket's path in the acceleration phase was 1314 (±175) mm, the variation coefficient was 13%. The racket's path in the deceleration phase was 1259 (±180) mm, the variation coefficient was 14%.

Such variability of the topspin forehand stroke among highly skilled tennis players indicates that athletes can use different options for performing this technique. The variability of the topspin stroke technique can be due to different mechanisms for accelerating the striking link and can be carried out according to the principle of the "whip" mechanism or according to the principle of the rigid rod mechanism [3, 5].

The «whip» mechanism involves sequential acceleration and sequential deceleration of the body links from proximal to distal, and the rigid rod mechanism involves acceleration of the kinematic chain as a single rigid structure. It is noted that these two mechanisms of acceleration of the striking link can be used by different athletes when performing the same type of striking actions in game sports and martial arts [1, 2]. The fact that our subjects accelerate the striking link differently when performing a top spin strike on the right is evidenced not only by the high variability of the kinematic characteristics in the experimental group, but also by the absence of statistically significant intragroup correlations between some kinematic characteristics, which logically should be very closely related to each other.

For example, the definition of the correlation between the maximum racket speed and other temporal and spatial characteristics of the top spin stroke on the right revealed the following. Of all the temporal phases of the top spin stroke on the right, only the time of the braking phase statistically significantly negatively correlates with the maximum racket speed. The correlation coefficient between these kinematic characteristics was – 0,88 (at $p \leq 0{,}01$). For the other temporal phases of the top spin stroke on the right, we did not find statistically significant correlations with the maximum racket speed.

We also found a positive statistically significant relationship between the maximum racket speed and the length of the racket path in the swing phase and in the braking phase when performing the top spin stroke. Thus, the correlation coefficient between the maximum racket speed and the path of its movement in the swing phase was 0.8 (at $p \leq 0.01$), and between the maximum racket speed and the path of its movement in the braking phase 0.83 (at $p \leq 0.01$). At the same time, we did not find a seemingly logical statistically significant relationship between the path of the racket in the acceleration phase and the maximum speed of the racket. The absence of seemingly logical statistically significant relationships between the maximum speed of the racket and some temporal and spatial characteristics of the topspin stroke on the right in table tennis among highly qualified athletes may be due to large interindividual differences in the technique of performing this stroke. It can be assumed that tennis players can use fundamentally different mechanisms for accelerating the striking link when performing this stroke. Determining these mechanisms and the features of their implementation based on a detailed study of the linear and angular velocities of the body links involved in accelerating the racket when performing the topspin stroke on the right is our further task.

Conclusions. Based on the analysis of the trajectory and speed of the racket, we determined the following kinematic characteristics of the forehand topspin: maximum racket speed; execution time of each of the three identified phases of the forehand topspin; racket path in each of the three identified phases of the impact action.

The kinematic characteristics of the forehand topspin for eight tennis players, as well as the average values and variation coefficients, are due to large interindividual differences in the technique of performing this stroke. It can be assumed that tennis players can use fundamentally different mechanisms for accelerating the impact link when performing the forehand topspin.

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