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Original Article

Flat shots analysis of tennis players

MAKSYM SUPRUNENKO
Kiev National University of Culture and Arts, UKRAINE
UDC 796.012.46

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Abstract:
Provide advantages and disadvantages of their use. The article uses personal observations and a theoretical generalized analysis of literary sources. The article is devoted to the study of flat strikes in tennis. Considered flat shots on the ball, bounced off the court and the use of a flat serve leading players and juniors. The article uses personal observations, the output of analytics of a flat shot, a theoretical generalized analysis of literary sources. The advantages and disadvantages of these blows are given. The analytical analysis of these shots with the initial speed is set out, depending on the angle of inclination to the horizon with distance h from the court plane. The resulted correction factors. The conditions for performing a flat serve are considered, and its advantages and disadvantages are given.
Key words: flat shot**,** flat *s*erve, analytics.

Introduction

Modern improvement of physical education in the university has long been the subject of many sports specialists studying. Much attention is paid to the sports interests of students, who will have to solve various social and economic problems **(**Zheleznyak ,2007; Vilensky 2013).

Sectional work in various sports attracts young people to physical activity and thus to improve their health and physical education. There is a process of initial preparation and teaching students the basics of tennis in the tennis section of our university. The main shots in tennis include giving serve, groundstroke (right and left), return serve, volley, half-volley, overhead, drop-shot and drop volley.

Successfully play an active game from the back line of the court and prepare net approach, only a tennis player who has a wide arsenal of shots on groundstroke can effectively defend. In the modern game, they use both flat shots, spin and slice (cut) shots groundies. The external picture of the movements to the groundstroke ball is quite similar. However, they are performed in various conditions to solve various tactical tasks, which causes them to differ from each other. One of the elements of learning to shot is learning to flat shot. In various sources, a flat shot is described in different ways. In various sources, a flat shot is described in different ways. L. Zaitseva believes that with flat shots, the angle rotation of the racket to the plane of the court to the outside, respectively, is 90-70 ° and 60-30 °. In other sources (Maksimov, 1998; Metzler, 2002) it is argued that with a flat shot, the plane of the racket is located vertically to the plane of th e court surface.

This is not always true. Belits-Geiman (1977, pp. 62-65) notes that the flat trajectory of the ball's flight will be with flat shots and shots with the rotation of the ball, in which the translational velocity vector will be perpendicular to the axis of the ball rotation. He also notes that when hitting the ball bounced off, the plane of the racket is positioned vertically to the plane of the court surface (Brown, 2009, p.87). Shots, after which the balls are sent to the side of the enemy without rotation, are called flat. They have the highest flight speed and are effectively used as attacking shots in response to the opponent's short and high balls (Golenko, Zaitseva, Tarpischev, 2001).

Material & methods

The following methods were used: theoretical analysis and generalization of literary sources of scientific and methodical literature; sociological methods (evaluation of the performance of a flat filing among juniors and leading players; analytical method for calculating motion parameters using kinematics; pedagogical observation (more than 100 classes of the university's tennis section).

Results

Integrating the knowledge of various sciences and their methods for solving problems of physical education and sports training makes it possible to move from subjective judgments about different aspects of the training and training process to accurate objective assessments and corresponding conclusions.

Corresponding Author: MAKSYM SUPRUNENKO, E-mail: supmax2016@gmail.com

The end of a racket swing determines how the shot will be: slice, spin or flat. It should be noted that the rectilinear and curvilinear trajectories, bent only in the vertical plane, are called flat. The trajectory of the ball sent by the player may be different. The decisive influence on it is the rotation of the ball during its flight.

It was found that a number of factors affect the ball's trajectory during a flat shot, such as:

- racket string surface;
- initial ball departure speed given to the ball by the racket;
- the angle of the ball and the angle of the racket to the surface of the court;
- height, relative to the floor at which the blow is being performed;
- air resistance which slows down the speed of the ball;
- the force of gravity, which turns the trajectory of rectilinear motion to the trajectory of motion close to parabalic;
- the value of the initial velocity;
- with the reflection of the ball from the rebound, the nature of the coverage of the court, etc.

The modern use of large controls (radar, new computer technology, software, high-speed video and other tools) allows you to study and improve the biomechanics of tennis strokes not only elite and professional tennis players. There are many tools for analyzing rational percussion actions of players of different levels.

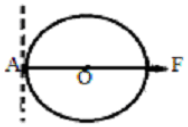

Fig. 1. Flat shot

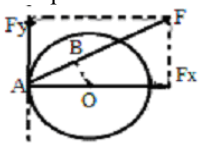

Fig. 2. Precision hitting

One of the laws of mechanics, which says: linear velocity depends largely on the force vector. With a flat kick (fig. I), the ball is not allowed to rotate, if the line of application of force exactly passes through the center of the ball - 0. In this case, the ball can only have a certain speed of translational motion, the motion does not have rotation. This is why flat shots are the most powerful.

If, when hitting the ball, the line of application of force F does not pass through the center of the ball (fig. II) - the movement is simultaneously directed upward and forward. From the center of the ball to this AF line, you can lower the perpendicular, then the distance BO can be viewed as a leverage. The appearance of the force shoulder lays down the force F acting on the ball to the force Fx, perpendicular to the plane of the racket and the force Fy parallel to the plane of the racket; the first gives the ball a progressive horizontal movement, and the second - rotational.

The greater the translational force, the faster the ball flies forward, while the greater the leverage of the rotational force, the more intense the rotation. As a result, the speed of the ball decreases accordingly.

Shot on the ball in tennis leads to a complex movement of the ball, consisting of two simple movements: a straight line directed along the x axis, parallel to the court surface and equally slow, directed downward perpendicular to the court surface. According to the laws of kinematics, we can derive dependences of the motion and speed of the ball's flight without taking into account air resistance:

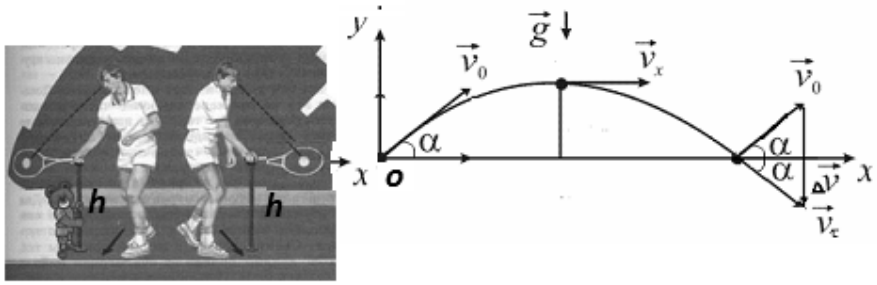

Fig. 3. Physical picture of a flat shot

Let the point of impact is at a height h above the plane of the court, and let the point of the ball fall lower than h relative to the point of impact. According to Fig. III, the coordinates of the movement will be written as:

$$X = V_0 t \cos \alpha \qquad (1); \qquad Y = V_0 t \sin \alpha - \frac{gt^2}{2} \qquad (2)$$

Projections vectors of instantaneous speed:

$$V_x = \frac{dx}{dt} = V_o \cos\alpha \quad (3); \qquad V_y = \frac{dy}{dt} = V_0 \sin\alpha - gt \quad (4)$$

From the formula (3) in the horizontal direction, the ball moves at a constant speed. $Y\tau = -h$,

The time of flight of the ball is determined, provided that at the time of the fall

$$-h = V_0\tau \sin a - g\tau^2/2 \quad \text{where does that} \quad \tau = \frac{V_0 \sin\alpha + \sqrt{V_o^2 \sin^2\alpha + 2gh}}{g} \quad (5)$$

Discard the negative root as such, which, according to the condition, has no physical meaning.

At the point of the highest ball lift up $V_y = 0, \quad 0 = V_0 \sin\alpha - gt_m$ therefore

where t_m - is the time it takes the ball to reach the highest point. From here,

$t_m = V_0 \sin\alpha / g$, and

substituting this value in (2), we obtain the magnitude of the greatest rise of the body above the horizontal plane:

$$Y_m = V_0 t_m \sin\alpha - gt_m^2/2 \quad = \quad V_0^2 \sin^2\alpha / 2g \quad (6)$$

The flight distance of the ball (the distance from the point of impact to the point of falling) is obtained by substituting the relation (5) into (1)

$$X_\tau = V_0\tau \cos a = V_0(V_0 \sin a + \sqrt{V_0^2 \sin^2 a + 2gh}) \cos a / g$$

The projections on the OY axis of the vector of the instantaneous speed of the ball at the time of the fall:

$$V_{y\tau} = \sqrt{V_0^2 \sin^2 a + 2gh}$$

and the instantaneous speed module at the time of the fall:

$$V_\tau = \sqrt{V_x^2 + V_{y\tau}^2} = \sqrt{V_0^2 \sin^2 a + V_0^2 \cos^2 a + 2gh} = \sqrt{V_0^2 + 2gh}$$

The formulas obtained make it possible to understand that the speed of the ball's flight, directed without rotation, depends on the initial velocity, the height of the point of impact, and without air resistance (vacuum).

When performing a flat shot, the stringed surface of the racket is fed almost to the center of the ball and is in a perpendicular position with respect to its direction of flight. The ball should be in the approximate direction to the horizontal, without rotation with a slight lift upwards. The advantage of a flat shot is in the swift, low, almost straight ball flight and low fast rebound. This kick allows you to create a fast paced game.

It should be noted that despite the installation of the players to perform flat shots, a players still give the ball a spin. For example, when the speed is 29 ± 8.8 m/s, the angular velocity is 8.1 ± 6.2 rev/s . The angular speed with spin and slice (cut) impacts is much greater. (Zaitseva, 2012, p. 12).

In a modern game, both flat, slice, spin shots slashed punches from a rebound are widely used. Each of them has an advantage in certain game situations, depending on the characteristics of court coverage, the opponent's game and a number of other factors. Most often, a flat shot is used when hitting a ball from a rebound at a high point, a overhead (smash) and a flat serve.

If the ball is directed to the opponent's side without rotation at high speed, then it may slip along the court surface with a subsequent minimum rebound height and maintain almost the same speed with which he arrived at the opponent's side. Such balls behave like pebbles, sliding on the surface of the water, or similarly to those that fall in line on the clay courts (down the line shot).

Rectilinear trajectories (or close to them) are characteristic of strong flat strokes - serve, shots overhead, and some fly strokes at the highest point. The serve accounts for about 30% of all strokes. A good serve can immediately bring a point or create prerequisites for his winnings. The inability to serve deprives a tennis player not only advantage, but also gives the opponent the ability to control the game.

The serve is the only stroke that is completely under the control of the player, and the opponent has no way to influence its execution. With flat shots, the ball flies low, fast, almost straight and bounces low. Flat strokes are more often used when the ball is reflected at a level above the net.

Factors affecting the flight path of the ball and its speed. This is the strength of the air resistance and the force of gravity. The force of gravity presses the ball to the ground, turning the rectilinear trajectory (shown in the figures) into a parabolic. Air resistance slows down the flight speed of the ball, increasing the time of flight to the touch of the court in both the horizontal and vertical directions. Data on the loss of speed when serving was obtained as a result of independent research to serve different tennis players (Sampras and Courier and

others). The feed speeds are fixed (digital displays on the courts) and measured at the time when the ball leaves the racket. By the time the ball reaches the surface of the court, air resistance and friction and hitting the surface of the court reduce its speed by about 50-55% due to air resistance, as well as when the ball hits the ground (Colligan,2009; Ranker Sports, 2018). Tennis instructor and analyst John Yandell has found that, on average, a 192 km/h serve slows to 131 km/h before the bounce, then to 104 km. / h after the bounce, and finally to 88 km/h at the opponent's racket (Colligan 2009, Fig. IV). Without taking into account these losses, any calculations of trajectories will lead to significant errors. Data are obtained for hardcore, for the soil - they are even more significant.

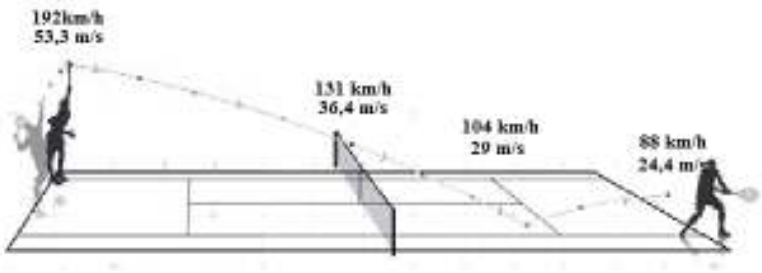

Fig. 4. Slowdown impact speed

Many coaches are absolutely mistaken in believing that a flat feed is possible only at a height of about 2.1 m. They mistakenly assume that the flight of the ball on a straight line trajectory with a flat feed and impact will hit the tennis net. As a result, it is considered that adolescents do not need to teach a flat serve, but to teach immediately spin serve with the rotation of the ball.

We make an assessment. The height of contact between the ball and the racket is somewhere around 2.5 m. Since the air is anisotropic medium (the properties of the medium do not depend on the direction). If you take the example of John Jandel (Fig. IV), then the average speed of the ball from the feed to the grid: Va = (Vo + Vg) / 2 = (53.3 + 36.4) / 2 = 44.85 m / s. For the distance we take the length of the hypotenuse of the triangle (Fig. V). The flight time of the ball to the net: t = S / Va = 12.2 / 44.85 = 0.27 s. During this time, not taking into account the force of air resistance, the ball will drop only h = $gt^2 / 2 = 9.8 * (0.27)^2 / 2 = 0.36$ m. And the distance of the ball to the net during the stroke at a distance of more than a meter.

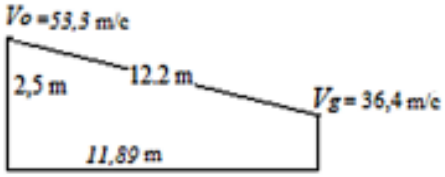

Fig. V. Flat server

Modernity requires from tennis player performing complex supply with different kinds of spin of the ball, does not allow to predict the opponent the flight of its flight. So in Andy Roddic, when flat serve at a speed of 248 km / h, the ball makes about 2500 revolutions per minute (41 rev / s).

The fastest blow of a man is recorded in the match Ivo Karlovic (Croatia) - 251 km / h. The fastest blow among women at Venus Williams with a speed of 205 km / h. We give statistics on the fastest player feed rate. No one can compete with the Australian Sam Groote, who in 2013 fired at a speed of 263.4 km / h; In Ivo Karlovich the fastest submission is 244.8 km / h, its submission is a nightmare for any player. Roger Federer can reach speeds of up to 230.6 km / h.

According to statistics, Roger Federer has 89% serve, which immediately earn points, Ivo Karlovich - 92%, Andy Roddik - 90%, Ivanishevich - 89%, Pete Sampras - 84.6%, Andy Murray -78.6% - 76.5%, Rafael Nadal - 76%, Andre Agassi -74.5%. Of course, these figures do not take into account the quality of the game of champions (Colligan 2009; Pravin, 2017; Ranker Sports, 2018).

The fastest is considered flat serve. Its straightness and predictability (No rotation) pushed it into the background. Flat serve brings the most winning points in both professional and amateur tennis. It is the most successful in comparison with others with variability spin. Elite players are more likely to use flat serve as the first serve. Roger Federer in his game applies different types of serves and shots including flat shot. Boris Becker's flat serve helped win Wimbledon three times.

Discussion

The time of the ball colliding with the racket is rather short, as evidenced by the work and research: Agashin (1977, 0.015-0.005 sec.), Vic Braden's Tennis Laboratory Koto de Casa (1997, 0.004 sec.), Kozenko 2008, 0.0031 s.), Zaitseva (2012, 0,01-0,005 s.), Golenko & Skorodumovoj (2001, 0.05 s.), M. Suprunenko (2009, 0.0052 s.), Rod Gross (2011, 0.005 s.). These authors have shown that "contact of the ball with the surface of the racket string lasts from 0.003 to 0.005 s. The ball leaves the surface of the strings of the racket before the central nervous system transmits a signal to the tennis player's brain, and he realizes that the ball has hit the target. It takes more than 0.001 seconds to send the corresponding message to the muscles in response to the racket strike signal. From this it follows that at the moment when a tennis player strikes a ball on a string with the surface of a racket, it is already too late to exert any influence on the control of a strike with a conventional or non-standard strike using the wiring to track the ball (Roetert Paul & Groppel Jask, 2004).

A racket is practically unable to drive (wiring) the ball, as it bounces off in a period of time that is difficult to see through shortness, the duration of which is equal to the duration of the deformation of the strings. It remains unconditional that the accuracy of the blow largely depends on the direction of the racket's movement into contact of the ball with the strings. It is necessary to maintain the correct orientation of the string surface of the racket as it moves toward the ball. But many authors argue that modern racquets, which have a larger area (length and width) compared to wooden ones, allow longer "lead" (wiring) a tennis ball on a racket, thereby giving it the right rotation. (Brown , 2009; Kharchenko 2006).

The strike time is so short that it is no longer possible to correct the mistakes made. Consequently, the accuracy of the strike is to a decisive extent ensured by the correct actions during execution and impact movement. To give more control over the ball, you need to continue its contact with the racket. After the racket collides with the ball, it must extend the movement in the direction of impact. The racket moves behind the ball, and does not end the movement and does not move back, long contact of the strings with the ball allows you to direct the ball in flight the longer, the longer they are together at impact. A short hit requires maximum precision. When the ball hits far from neutral points, including not in the center of the string field of the racket, there are unpleasant sensations, which makes it beat more gently, so as not to feel any pain from the racket vibration (Singleton , 2004).

Longer support of the ball with a racket creates longer safety in the zone of contact of the stringed surface with the ball. However, it turned out that this is to some extent inconvenient, which hinders the movement of a tennis player who performs a racket hit on the ball (Roeter & Groppel, 2004, pp.191-192). The concept of "flat shot" is somewhat arbitrary, since any shot in tennis gives the ball a certain rotation, although the degree of rotation can differ significantly (Singleton , 2004).

Conclusions

Powerful and at the same time the most difficult to perform are flat shots, in which the ball is not given rotation.

1. The factors affecting the trajectory of the ball.

2. The analytical dependence of the instantaneous and final speed, range and altitude of the ball on the mechanical parameters without taking into account the air resistance is derived.

3. It was found out by how many percent the actual speed may change when shot and serve.

It should be noted that flat strikes, which are characterized by high ball speed, unlike others, have the least stability in their result. They are effective when playing fast courts, and especially when playing strong against an opponent.

Shots can be performed at various points in height: high (above the shoulders of the player), medium (at the waist) and low (above the knees and below). A tennis player can hit a rising ball at the highest point of the rebound and a falling ball. Usually they try to hit a growing ball in order to better utilize the speed of the flying ball. Flat strikes are used when hitting the ball, which bounced off the ground plane at the middle and high point. When used at the lowest point, the ball often flies off the court. As a first serve, most players use a flat serve.

Conflicts of interest

No conflicts of interest.

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