THE INFLUENCE OF BODY HEIGHT ON THE SERVE IN TENNIS

Frantisek Vaverka, Miroslav Cernosek, Katerina Tesarova and Milan Elfmark
Faculty of Physical Culture, Palacky University, Olomouc, Czech Republic

A theoretical model expressing the relationship between the dimensions of the tennis court and the height at which the ball is stroked when served is the starting point for a study of the influence of the body height of a player on the serve in tennis. A model of the flight of the ball expressed as a straight line has provided us with the theoretical information we need at the beginning regarding the angle of the serve and the active distance of the impact of the ball as dependent on the height at which the ball is stroked. The characteristics of the model were confronted with the real values acquired in a kinematic analysis of the first and second serves of two top world-class players. An increase in the height of a player appears to be a dominant factor which positively influences the direction of the flight of the ball and the speed of the serve.

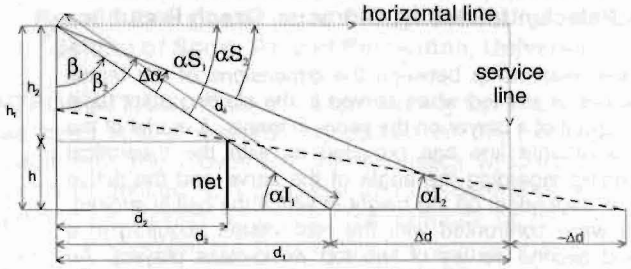
KEY WORDS: serve, body height, model, kinematic analysis

INTRODUCTION: The quality of the serve is influenced by a whole row of factors, which can be, briefly, divided into the following categories: the dimensions of the tennis court and the height of the net, aerodynamic conditions for the ball in flight, the height at which the ball is stroked, the technical quality of the racket and the ball, the performance of the serve and the technique used (which depends on the level of the movement abilities of the athlete and the state of the organism, his fatigue and the like), the strategic and tactical solution of the given situation and further factors. In existence are tens of scientific and scholarly works and biomechanical analyses describing the performance of the serve, the aerodynamic conditions of the flight of the ball and technical issues regarding the interaction of the ball and the racket (for example: Haake & Coe, 2000; Miller, 2003). So far no serious attention has been paid to the question of the influence of the basic conditions determining the performance of the serve, which are the dimensions of the court and the height of the net. The given problem is very closely connected with the height of the ball at the moment it is stroked, which is connected to the body height of the tennis player.

PROBLEM: The track of the flight of the ball describes the ballistic curve due to the gravitational force as well as aerodynamic forces. Dunlop (2000) presented the movement equations for the track of the flight of the ball, including the ballistic curve and changes in the speed of the flying ball. The track of the flight of the ball is influenced by aerodynamic forces, where air resistance plays the most important role in a loss of speed (Dunlop, 2000). Rotation of the ball – lift significantly influences the shape of the track of the flight (Chadwick, 2000). With an increase in the speed of the ball, the ballistic curve is coming closer to a straight line. The simplest theoretical model of the track of the ball in flight is the straight line. In the presented study we are interested in how the size of the active distance of the impact of the ball into the serve area depends on the height at which the ball is stroked and the dimensions of the tennis court. The height at which the ball is stroked depends on the body height of the player and the quality of the serve. The goal of this study is to establish the angle of serve available to the player as related to body height and the active distance of the impact of the ball from the serve line. The observed variables of the theoretical model of the course of the flight of the ball as expressed by a straight line is confronted with the values calculated with the help of a kinematic analysis of the real performances of the first and second serves of two world-class players.

METHODS: The theoretical model of the course of the flight of the ball as expressed by a straight line was, in connection with the dimensions of the tennis court, the height of the net and the height at which the ball was stroked is the starting point for the calculation of the angle of serve ($\Delta\alpha$), the active distance of the impact of the ball from the serve line (Δd), the initial direction of the flight of the ball after serve (αS) and the angle of the impact of the ball

into the service area (αI). In Figure 1, the initial quantities and algorithms necessary for calculation are schematically represented.



a

$$\alpha I_1 ... tg\,\alpha I_1 = \frac{h_2}{d_2} \qquad \beta_1 ... \beta_1 = 90 - \alpha I_1$$

$$d_3 ... d_3 = \frac{h_1}{tg\,\alpha I_1} \qquad \Delta\alpha ... \Delta\alpha = \alpha S_1 - \alpha S_2$$

$$\beta_2 ... tg\beta_2 = \frac{d_1}{h_1} \qquad \Delta d ... \Delta d = d_1 - d_3$$

b

Figure 1 A theoretical model for the calculation of the observed quantities: graphic illustration; b – algorithms of the calculation of observed quantities.

The establishment of the height at which the ball is stroked was taken from real values of the body height of the best tennis players, which ranges, in men, from 170-205 cm and in women from 150-195 cm. (Vaverka et al.). It is necessary to add the length of the player's arms to the body height of the player (40-50 cm), the distance from the place where the ball is released from the grip of the player (approximately 45 cm) and in some cases the height of the jump when the ball is stroked (10-20 cm). In view of the above-mentioned dimensions, we have, to a height of stroking the ball of 230-310 cm, added an approximate body height of the player ranging from 125-205 cm. A kinematic analysis of the observed variables was carried out by two top world-class players (with a placement to the 30th place in the ATP ranking) under real conditions during a semifinals match at an ATP tournament (player RS, body height 185 cm, 13 first and 5 second serves and player DH, body height 183 cm, 10 first and 5 second serves) were evaluated. In a 2D regime, 2 cameras proved to be of use (Panasonic NV-MX500EG, 1/1000 s, 25 Hz.), the serve and impact phases were recorded. By using the APAS system (50 Hz) the track of the ball was digitized, smoothened, and from the equation of the track of the ball after 0.02 s after stroke, the velocity of the serve (VS) and the direction of this velocity (αS) has been computed (Figure 2).

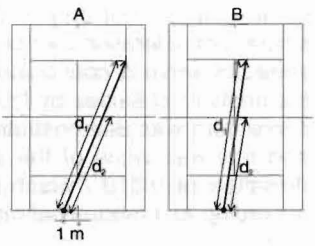
Figure 2 Kinematic analysis of the flight path of the ball after serve and measured variables.

In a similar way, the speed of the impact (VI) and the angle of the impact (αI) were calculated. Methods from the system Statistica v6 (basic statistical characteristics, the Mann-Whitney U test of the difference between two sets and the paired t-test) were used for the statistical analysis of measured data.

RESULTS: The results of the theoretical calculation are given in Table 1.

Table 1 Theoretical model of the flight path of the ball in serve – calculation of the observed quantities.

h'	h1	Serve to the sideline A			Serve to the centre serve line B		
		Δα	αS	Δd	Δα	αS	Δd
1.25	2.3	-0.664	6.907	-2.038	-0.685	7.127	-1.976
1.35	2.4	-0.503	7.204	-1.44	-0.519	7.434	-1.395
1.45	2.5	-0.342	7.501	-0.917	-0.353	7.74	-0.889
1.55	2.6	-0.182	7.797	-0.46	-0.187	8.045	-0.445
1.65	2.7	-0.022	8.093	-0.053	-0.024	8.351	-0.053
1.75	2.8	0.137	8.389	0.31	0.141	8.655	0.299
1.85	2.9	0.295	8.684	0.634	0.303	8.96	0.613
1.95	3	0.452	8.979	0.926	0.466	9.263	0.897
2.05	3.1	0.61	9.273	1.194	0.628	9.566	1.155



h' – estimated body height of the athlete, h1 – height of stroked ball.

A confrontation of the sums of quantities in both serve directions points up very small differences in the size of the calculated quantities between a serve to the sideline as opposed to the centre serve line. The size of the angle of serve Δα is very small and ranges from 0.14° for a stroke height of 280 cm to 0.61° for a stroke height of 301 cm. The given angle for the height of a stroke lower than 280 cm is theoretically negative, which means that the service trajectory of the ball would not land in the service area. With a change of the angle of the serve by a value of 0.16°, the size of the active distance of the serve grows by a value of nearly 0.27 m. The size of the angle of the initial direction of the flight of the ball after service, with the values of the height at which the ball is stroked being 280-310 cm, between approximately 8.4° to 9.4° (the range about 1°).

Results of a kinematic analysis of real performance of the serve by two top world-class players are given in the Table 2.

Table 2 A kinematic analysis of the 1st and 2nd serve by players RS and DH. A statistical analysis of the differences between two sportsmen.

	Serve	RS		DH		Idl	Z	p
		MEAN	S.D.	MEAN	S.D.			
VS	1.	183.09	18.43	176.67	14.72	6.42	0.930	0.376
	2.	152.42	10.34	135.71	8.10	16.71	2.193	0.032*
αS	1.	3.019	0.318	2.964	0.589	0.055	0.558	0.605
	2.	2.278	0.460	1.433	0.761	0.845	1.567	0.151
vl	1.	136.97	17.31	131.85	15.40	5.120	0.992	0.343
	2.	114.41	11.94	99.31	11.59	15.1	1.776	0.095
αl	1.	10.335	0.951	10.70	0.650	0.365	-0.620	0.563
	2.	12.565	0.373	14.737	1.017	2.172	-2.611	0.008**

* $p < 0.05$; ** $p < 0.01$

Speed of the 1st serve RS is somewhat higher on the average, but with a moderately larger variability of values (MIN = 151.31 km.h^{-1}, MAX = 206.43 km.h^{-1}) than we see in the case of the player DH (MIN=154.36 km.h^{-1}, MAX= 198.99 km.h^{-1}). The difference between the degree of speed of the first serve corresponds to the angular value of the initial direction of the flight of the ball S, which is, in the case of RS at higher speeds (the ballistic curve is flatter), greater than in the case of DH. The speed of the ball during its impact onto the ground in the service area was reduced in the cases of both players to 75% in agreement with the Dunlop study (2000). Also the angle of the impact of the ball into the service area corresponds logically with the ballistic flight path of the ball.

DISCUSSION: The angular values of the real ballistic curves of the analysed serves are in agreement with the general laws for the flight of a ball. A theoretical analysis of the flight path expressed as a straight line has brought us to a clear conclusion about the influence of the height of the stroke on the αS and Δd. With increasing body height, the angle of the serve S and the size of Δd also increase. With the growing speed of the serve the value of the initial angle of the serve αS increases and with decreasing speed the angle is decreased. The trend we are speaking of has been clearly demonstrated by confrontation of the performance of two players not only in the situation of the first serve, but also of the second serve. A similar consideration can be applied to the angle of the impact of the ball αI, when a higher speed of serve is connected with a smaller angle of the impact and vice versa. The result of the analysis of serves by RS, who succeeded in achieving a greater speed in the 1st and 2nd serve than was demonstrated by DH, shows us that the variable span between the minimal and maximal value of the angle of the serve makes up approximately 1^0 with a standard deviation of 0.318^0, which is in agreement with the count resulting from the calculations according to a theoretical model.

CONCLUSIONS: The result of the theoretical analysis of the influence of height on stroking the ball during serve on the flight path was in agreement with the results of the kinematic analysis. The angle of the serve and the active distance of the impact of the ball into the service area is increased with an increase in body height and makes it possible to increase the speed of the serve. Kinematic analyses of the 1st and 2nd serves of two top world-class players confirmed the conclusions we drew based on the calculations acquired with a theoretical model and suggest that there is the possibility of practical application of this information into training.

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