DIFFERENCES IN KINEMATIC PARAMETERS BETWEEN FIRST AND SECOND SERVES IN TENNIS BY ELITE PLAYERS OF THE GERMAN LEAGUE

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Abstract
The primary goal of this research was to determine the differences in kinematic parameters between the first and second serves in tennis among the elite players of the German league. The sample of respondents in this research consisted of 30 elite male senior players of the German League who have "Leistungklasse" from 1 to 7. The kinematic parameters that were analyzed are: Height of ball impact (KPVUL), Racket speed (KPBRE), Ball speed (KPBLO), The angle at the elbow joint of the arm that hits the ball (KPULZ), Oscillation of the vertical projection of the center of gravity of the body (KPOVP), Jump height (KPVSK), Ball launch height (KPVIL), The point of contact between the ball and the racket "sweetspot" (KPMLR), Ball rotation "Top spin" (KPRLO). The video recording required for kinematic analysis was acquired with two Casio EX-F1 digital cameras at a frequency of 200 images per second. The camera was placed at an angle of 90^0 in relation to the recording plane, and they were at a distance of 10 m. Space calibration was performed with the help of a calibration frame (200 x 200 cm). We have installed Zepp Tennis Smart Sensor 2.0 in the handle of the Wilson Pro Staff RF97 Autograph racket, using the Zepp Tennis application software. "Kinovea" software was used for service analysis and obtaining kinematic parameters from video recordings. By analyzing the results of the T-test for independent samples, it can be seen that there are statistically significant differences in five of the nine analyzed kinematic parameters : KPBRE – kinematic parameter of racket speed (Sig.=.000), KPBLO – kinematic parameter of ball speed (Sig.=.000), KPULZ – kinematic parameter angle in the elbow joint (Sig.=.000), KPMLR – kinematic parameter point of contact between the ball and the racket (Sig.=.000), as well as a variable KPRLO – kinematic parameter of ball rotation (Sig.=.000). Larger numeric values in variables: KPVUL – kinematic parameter ball impact height, KPOVP – kinematic parameter of oscillation of the vertical projection of the center of gravity of the body, KPVSK – kinematic parameter jump height and KPVIL – kinematic parameter ball impact height, show a difference but it is not enough to be statistically different.
Key words: tennis, kinematic analysis, racket speed, Zepp sensor

INTRODUCTION

The serve is a very important factor in the tennis game and puts enormous pressure on the opponent (Yang et al., 2015). Đulović et al. (2005) in their research, state that the tennis serve is one of the most important elements of a successful tennis player's technique. It is a skill over which the players have complete control (Sun et al., 2012). It is also one of the most difficult shots to perform as an activity of throwing the ball, then hitting it on the downward trajectory. It requires complex multi-segmental coordination between the ball, the hitting part of the body, the trunk and the lower extremities (Bahamonde, 2000). It is a skill that is classified as a movement pattern of the hand where the main goal is to achieve the appropriate trajectory and optimal speed of the racket at impact (Subijana and Navarro, 2009). Players usually serve over the head, while hitting the ball below the level of the head is allowed but rare. For beginners, the serve is a difficult shot, but once mastered it is a significant advantage. Successful players can serve in a number of ways, and often use it as an offensive tool to try to gain an advantage in a point, or to win it outright. Precisely because of this, professional players are expected to win most of their serves, i.e. games, and winning the opponent's serve (break) plays an important role in winning the match. In this research, we will look for differences between 2 types of service: the first service as a flat service and the second service as a kick service. The rules do not separate the first and second serves, but the serving tactics differ. Since it was shown that serves have different performance techniques, researchers have examined the kinematics of individual parts of the body, the tennis racket as well as the throwing of the tennis ball. (Sheets, 2011).

The first serve is usually hit with maximum power, with ultimate skill, when a player's mistake is also possible due to the effort to win a point immediately after the serve, or already after the next shot by putting the opponent in a subordinate position. The second serve is usually more conservative, to avoid a double serve fault, and is usually hit with less power or so that the trajectory

of the ball is more curved. A flat serve (formerly known as a cannon ball) is a shot with an Eastern or Continental grip, and with a path of impact directly on the ball, so that the ball does not rotate and cuts through the air very quickly during movement. During the flat serve, higher horizontal, vertical and absolute speeds are developed, while the lateral speeds are characteristic of the kick serve. Professional men's tennis players hit the ball with this service so that it reaches up to 200 km/h (Chiang et al., 2007), and a few women's tennis players also perform such fast shots. The ball on this serve has to go close to the net, so it doesn't leave much room for mistakes. Because of this, in this service the ball falls to the center of the court, crossing the net where it is lowest, and they are usually made as first serves when the player can afford to risk serving. The twist serve, initially known as the American twist serve, is a special type of topspin-slice serve that behaves differently on the bounce, because it carries more topspin than sidespin. Instead of drifting and continuing to turn left (from the server's perspective) after the bounce as is the case in all slice serves, the ball rakes forward, straight to the backhand of the player receiving the serve (if he is right-handed). Like all spin serves, the ball can go high over the net leaving less chance for error. This, along with the awkward bounce, makes this serve a popular second serve choice. To produce the required topspin-to-sidespin ratio, the ball must have a twisted axis of rotation, so that the ball rotates out of its path (when viewed from above, the axis of rotation of the ball rotates slightly counter-clockwise). The ball is thrown behind and to the left of the serviceman's head. Using the Continental, or more commonly Eastern Backhand grip, a player almost always swings the racket by hitting the ball in one of two positions: a 7 o'clock to 1 o'clock stroke, or more commonly an 8 to 2 o'clock stroke. Hitting the ball with different angles and speeds depends on the goal, where you want the ball to fall and how it bounces in the opponent's court, which reduces the predictability of the trajectory for the receiver of the serve, and increases the chances of winning point for the server. In some regions, the American twist serve is also known as the reverse side spin serve.

METHODS

Participants

The sample of respondents in this research consisted of 30 elite male senior players of the German League who have "Leistungklasse" (LK) or quality level from 1 to 7 (LK, 2023).

Variables

The measuring instruments of this research were kinematic parameters: Height of ball impact (KPVUL), Racket speed (KPBRE), Ball speed (KPBLO), The angle at the elbow joint of the arm that hits the ball (KPULZ), Oscillation of the vertical projection of the center of gravity of the body (KPOVP), Jump height (KPVSK), Ball launch height (KPVIL), The point of contact between the ball and the racket "sweetspot" (KPMLR), Ball rotation "Top spin" (KPRLO).

Procedure

Data collection was carried out on the tennis courts of TC "Viktoria" Koln. There was a certain position from which to serve, and on the other side of the field there was a space with dimensions of 1x1 m2 as a target. The video recording required for kinematic analysis was acquired with two Casio EX-F1 digital cameras at a frequency of 200 images per second. The camera was placed at an angle of 90^0 in relation to the recording plane, and they were at a distance of 10 m. Space calibration was performed with the help of a calibration frame (200 x 200 cm), and all for the purpose of enabling precise calibration of space during analysis. We have installed Zepp Tennis Smart Sensor 2.0 (ZTSS, 2023) in the handle of the Wilson Pro Staff RF97 Autograph racket, using the Zepp Tennis application software. Before the performance of the service itself, selected entities from the population of elite tennis players of the German League and possessing LK 1-7 warmed up and prepared for testing. After the aforementioned preparations have been completed, they come to the court individually and each of them serves the first serve as a flat serve and the second as a kick serve. They served into the service field and the target on a certain part of the court with dimensions of 1x1 m. For the purposes of service analysis and obtaining kinematic parameters from video recordings, the "Kinovea" software was used, and the obtained data were entered and analyzed in the IBM SPSS 20 (Statistical Package for the Social Sciences).

Data analysis

In order to determine the differences between the first and second serve in tennis among the elite players of the German League who have LK 1-7, we used the T-test for small independent samples.

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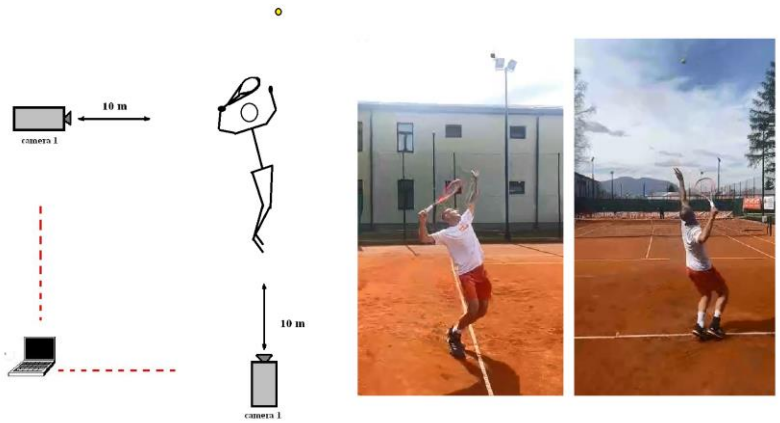

Figure 1. Schematic representation of polygons for kinematic analysis

RESULTS and DISCUSSION

Table 1 presents a set of central and dispersion parameters of applied kinematic variables of the first serve in tennis. The following values were calculated for all variables: range, minimum and maximum value, arithmetic mean, standard deviation, variance, skewness, kurtosis and coefficient of variability. By calculating the coefficient of variability of the kinematic variables, i.e. what percentage of the arithmetic mean is the value of the standard deviation, we obtained that the variable kinematic parameters of the oscillation of the vertical projection of the center of gravity of the body (KPOVP: Std.Deviation: 9,37977; Mean: 24,7733; coeff. vari: 37,8%) and the variable kinematic parameters of the jump height (KPVSK: Std.Deviation: 6,29329; Mean: 19,9870; coeff. vari: 31,4%) vary the most. Analyzing the skewness value, i.e. analyzing the normality parameters of the distribution of the results, it is evident that the skewness results of most variables are positive, and the other values are around zero, which tells us about a normal distribution.

Table 1. Central and dispersion parameters of kinematic variables of the first serve in tennis

	N	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness	Kurtosis	KV
KPVUL	30	116,68	263,42	380,10	313,45	32,79	1074,93	0,61	-0,36	10,45
KPBRE	30	51,00	107,00	158,00	135,57	13,80	190,39	-0,03	-0,73	10,17
KPBLO	30	47,00	160,00	207,00	186,47	11,89	141,36	-0,20	-0,36	6,37
KPULZ	30	21,00	71,00	92,00	82,60	6,24	38,94	-0,50	-0,89	7,55
KPOVP	30	31,22	10,86	42,08	24,77	9,38	87,98	0,61	-0,54	37,86
KPVSK	30	25,59	8,51	34,10	19,99	6,29	39,61	0,06	-0,70	31,48
KPVIL	30	178,75	302,20	480,95	392,20	43,21	1867,25	-0,08	-0,02	11,01
KPMLR	30	21,00	79,00	100,00	88,03	5,71	32,65	0,09	-0,59	6,49
KPLRO	30	979,00	624,00	1603,0	960,87	230,82	53278,4	0,96	0,87	24,02
Valid N (listwise)	30									

Table 2 presents a set of central and dispersion parameters of applied kinematic variables of the second serve in tennis. As with the first one, we calculated following values for all variables: range, minimum and maximum value, arithmetic mean, standard deviation, variance, skewness, kurtosis

and coefficient of variability. By calculating the coefficient of variability of the kinematic variables, i.e. what percentage of the arithmetic mean is the value of the standard deviation, we obtained that the variable the kinematic parameter of the jump height (KPVSK: Std.Deviation: 6,75815; Mean: 22,3107; coeff. vari: 30,29%) vary the most. Analyzing the value of the skewness of most variables that move around zero, we can say that the distribution is normal, except for the skewness of the kinematic parameter of ball impact height (KPVUL), indicating an epicurtic distribution (positive left skewness). Analyzing the value of kurtosis, we can say that it does not differ from normal for most variables. We have higher values for the variables kinematic parameter ball impact height (KPVUL) and kinematic parameter jump height (KPVSK), which indicates a platykurtic distribution.

Table 2. Central and dispersion parameters of kinematic variables of the second serve in tennis

	N	Range	Min	Max	Mean	Std. Deviation	Variance	Skewness	Kurtosis	KV
KPVUL	30	123,31	263,84	387,15	308,37	32,08	1028,97	1,28	1,50	10,40
KPBRE	30	40,00	76,00	116,00	98,11	11,18	125,07	-0,29	-0,35	11,39
KPBLO	30	35,00	121,00	156,00	141,40	9,69	93,93	-0,60	-0,19	6,85
KPULZ	30	42,00	30,00	72,00	47,97	13,09	171,27	0,56	-0,78	27,28
KPOVP	30	21,81	10,08	31,89	23,09	6,18	38,22	-0,47	-0,56	26,76
KPVSK	30	29,58	9,29	38,87	22,31	6,76	45,67	0,91	1,08	30,29
KPVIL	30	180,35	304,18	484,53	382,11	41,58	1729,14	0,43	0,00	10,88
KPMLR	30	51,00	25,00	76,00	57,37	14,68	215,41	-0,59	-0,83	25,58
KPLRO	30	1747,0	1508,0	3255,0	2602,2	476,41	226964,4	-0,81	-0,09	18,30
Valid N	30									

Table 3. Descriptive parameters for analyzing variables of research groups of the first and second services

	Group	N	Mean	Std. Deviation	Std. Error Mean
KPVUL	First service	30	313,45	32,79	5,99
	Second service	30	308,37	32,08	5,86
BPBRE	First service	30	135,57	13,80	2,52
	Second service	30	98,11	11,18	2,04
KPBLO	First service	30	186,47	11,89	2,17
	Second service	30	141,40	9,69	1,77
KPULZ	First service	30	82,60	6,24	1,14
	Second service	30	47,97	13,09	2,39
KPOVP	First service	30	24,77	9,38	1,71
	Second service	30	23,09	6,18	1,13
KPVSK	First service	30	19,99	6,29	1,15
	Second service	30	22,31	6,76	1,23
KPVIL	First service	30	392,20	43,21	7,89
	Second service	30	382,11	41,58	7,59
KPMLR	First service	30	88,03	5,71	1,04
	Second service	30	57,37	14,68	2,68
KPLRO	First service	30	960,87	230,82	42,14
	Second service	30	2602,20	476,41	86,98

By analyzing the results of the T-test (Table 4) for independent samples, it can be seen that there are statistically significant differences in five of the nine kinematic parameters KPBRE (Sig.=.000), KPBLO (Sig.=.000), KPULZ (Sig.=.000), KPMLR (Sig.=.000) and KPRLO (Sig.=.000).

Larger numerical values visible in Table 3 in variables KPVUL, KPOVP, KPVSK and KPVIL they

have a difference, but it is not enough to be statistically different.

In a paper related to the Kinematic analysis of the service technique of the world elite tennis player Novak Đoković (Yang et al., 2015), they explained that the serve is a very important factor in the tennis game, that at the beginning of the point, huge pressure would be put on the opponent and that it would be easier to reach the point. Technique plays a very important role in tennis competition, and it is an important segment for achieving top results. Research on the speed of the ball during the serve (Martin, 2014) showed us that the players who were the best at that tournament had the fastest and most efficient first serve. They reached points more easily and that the first serve was a key element of successful play. Wong et al. (2010) proved that the speed of the first serve of players from Hong Kong is significantly slower (cc 40 km/h) compared to the best Olympic tennis players. This research can be one of our conclusions that the first serve must be a weapon with which we attack and lead the match. All of the above can be a significant conclusion for connecting two kinematic parameters KPBRE (kinematic parameter of racket speed) i KPBLO (kinematic parameter of the speed of the ball). The reason for the difference between the first straight and the second kick serve is precisely the speed of the racket and the speed of the ball, which significantly affect the game of each individual. The higher the percentage of the first serve thrown, the more pressure is put on the opponent who does not have an adequate response and enables the players who have the serve as an opening shot, to reach points more easily. In a study conducted by Reid et al. (2007), they compared the kinematics of the whole body during flat and kick serves. They proved that flat serves have higher horizontal, vertical and absolute speeds, while kick serves are characterized by lateral speeds. This means that the player serving the second serve could give the ball more spin which would give him more safety, more bounce of the ball and increase the chances of the opponent not being able to attack him on his weaker second serve.

Table 4. Results of the T-test for independent samples

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
KPVUL	0,38	0,54	0,61	58,00	0,55	5,08	8,37	-11,68	21,84
KPBRE	1,35	0,25	11,55	58,00	0,00	37,45	3,24	30,96	43,94
KPBLO	1,34	0,25	16,09	58,00	0,00	45,07	2,80	39,46	50,68
KPULZ	5,05	0,03	5,80	58,00	0,00	22,47	3,88	14,71	30,23
KPOVP	3,83	0,06	0,82	58,00	0,42	1,68	2,05	-2,43	5,78
KPVSK	0,24	0,63	-1,38	58,00	0,17	-2,32	1,69	-5,70	1,05
KPVIL	0,00	0,96	0,92	58,00	0,36	10,10	10,95	-11,82	32,01
KPMLR	33,14	0,00	10,66	58,00	0,00	30,67	2,88	24,91	36,42
KPRLO	10,62	0,00	-16,98	58,00	0,00	-1641,33	96,65	-1834,80	-1447,87

Chiang et al. (2007), when performing straight and top spin serves, stated that in modern tennis competition, the serve is one of the winning and key factors. Highly skilled tennis players usually use a straight first serve and a slice or top spin serve for the second serve. It is stated here that with professional players the first serve goes over 200 km/h. But they proved that the biggest difference between professionals and amateurs is in the second service. The reason could be that they have to hit a precisely imagined point where the opponent could not attack them. This is exactly what requires enormous concentration and the ability to produce enormous rotation with a precisely determined point of contact between the ball and the racket, to produce its own force and transfer it to the ball, which should go towards the opponent in the imagined point. Reid et al. (2007) in their research on the experimental study of kinematics on quality service in the tennis game, state that the research studied the effective parameters of quality service. They only used a

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comparison in quality or second serve between 8 Iranian professional players and 8 Iranian players who train 3 times a week. They concluded that professional players have better effective parameters, i.e. they produce greater lateral forces with their own strength to give greater rotation of the ball, which gives them greater security in the game. The mentioned research can be a significant conclusion for us to connect two kinematic parameters KPMLR (kinematic parameter point of contact between the ball and the racket) and KPRLO (kinematic parameter of ball rotation) and that the difference between the first and second serve are also two parameters that affect every individual who plays tennis. The kinematic parameter, the so-called sweetspot, which we obtained with the Zepp instrument, tells us about the contact point on the racket head. It is interesting that with the second service, that sweetspot is numerically much smaller compared to the numerical value of the first service (Figure 2). The kinematic parameter of ball rotation, which we also get with the help of the Zepp sensor, tells us that in the second serve we have much higher numerical values compared to the first serve.

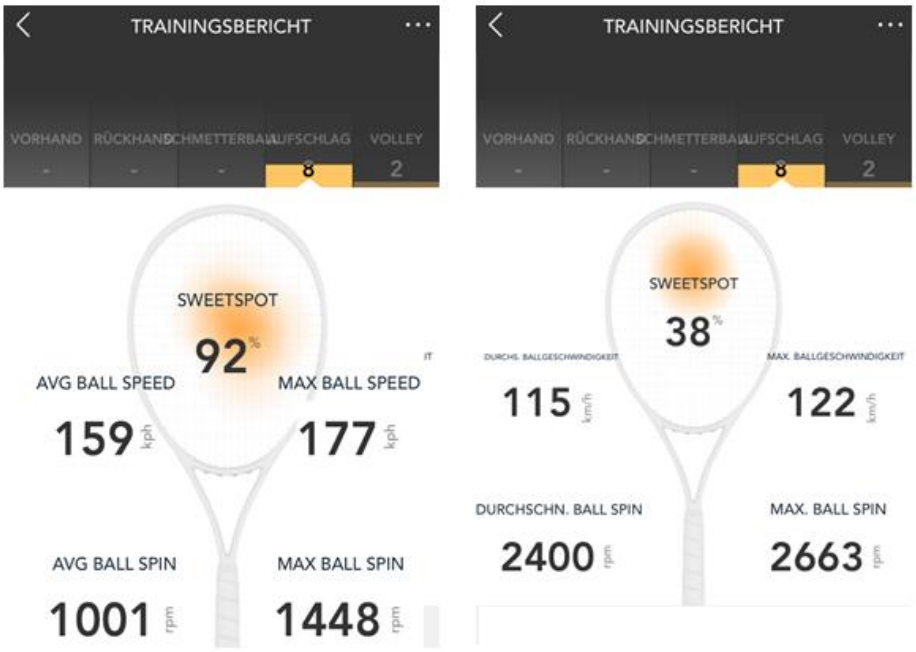

Figure 2. Numerical values of the Zepp sensor of the first and second service

CONCLUSION

Based on the obtained results, we can say that there are differences between the first and second serves in tennis, and this can result in technical-tactical requirements of the tennis game itself. Depending on the moment, duration and importance of points, variations in tennis are allowed, however, through past experiences, most tennis players do not calculate during the match as far as the first and second serves are concerned. Future research could go in the direction of determining the differences between all three types of services and take into consideration as many kinematic parameters as possible, in order to determine the real differences between services. Likewise, due to today's advancement of technique and technology applied in sports, future research could be challenging as factors that affect the quality of players. Also, one of the ideas for future research could be the differences between successful and unsuccessful services, because we believe that it is impossible to prove which error occurs during an unsuccessful service. All coaches who work with players should encourage them to learn as many types of service techniques as possible, as this would affect their development and their diversity in shots. In the same way, trainers should be well educated and follow new techniques and trends that are currently prevailing on the world stage. They need their knowledge and experience to transfer to their players, who in turn need to be disciplined. It is this research that shows us how complex the tennis game is by noting that we took into consideration only one technical segment in tennis.

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