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Association between serve speed and court surface in tennis

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ABSTRACT

The aim of the study was to determine whether the serve speed differs between Grand Slam tournaments (GSTs) played on different court surfaces. The study was carried out for both men and women (n = 70–98) who participated in four of the GSTs in 2008, 2012 and 2016 (Australian Open, French Open, Wimbledon and US Open). The following serve-speed parameters were obtained from the official GST websites: the speed of the fastest serve (FS), the average speed of the first serve in a given match (S1) and the average speed of the second serve in a given match (S2). Statistical analysis was performed using a mixed linear model procedure (NCSS 2007, Keysville, UT). FS varied irregularly, but it did not differ significantly between GSTs in the three observed years. The values of S1 and S2 for both men and women were highest in WIM in all three years, and were significantly higher than the other variables measured at the other GSTs. An association between serve speed and tennis court surface was confirmed only for S1 and S2 at fast grass court surfaces at WIM in the period 2008–2016.

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Tennis elite players; Grand Slam tournaments; serve strategy; serve speed variations

1. Introduction

The serve speed in tennis is influenced by numerous factors, including the technique and biomechanics of the serve (Brody, 1987; Elliott, Reid, & Crespo, 2003, 2009; Knudson, 2006), the motor precondition (Grosser, Kraft, & Schönborn, 2000), body dimensions (Vaverka & Cernošek, 2013), physical qualities of the racket and string tension (Brody, Cross, & Lindsey, 2007) and the balls (Blackwell & Knudson, 2002; Bower & Cross, 2005; Haake, Allen, Choppin, & Goodwill, 2007). Also, environmental conditions affect serve execution, such as light levels (i.e. sunlight or artificial light), random wind (Mendes et al., 2012) and the spectator atmosphere.

The court surface influences the direction, speed and spin of a tennis ball after impact (Brody, 1987; Brody, Cross, & Lindsey, 2002; Lees, 2003; Miller, 2006), as well as the player's movement and the probability of an injury in extreme movement situations (Barnett & Pollard, 2007; Cross, 2006; Dragoo & Braun, 2010), time – motion of players (Galé-Ansodi, Castellano, & Usabiaga, 2016) and the duration of the time serve and strokes (Takahashi et al., 2006). The quality of the court surface affects the duration of

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rallies and serving strategies (O'Donoghue & Ballantyne, 2004; O'Donoghue & Ingram, 2001; Unierzyski & Wieczorek, 2004). The influence of the surface on the ball bounce increases with ball speed, which means that the effects are greatest during serves (Brody et al., 2007).

The International Tennis Federation classification divides court surfaces into 5 categories according to their pace rating, which is related to the effect of ball–surface interaction (slow, medium slow, medium, medium fast and fast) and involves more than 150 variants of existing surfaces (International Tennis Federation, 2007). Extreme surfaces that exhibit substantially different physical characteristics are clay (slow) and grass (fast). Among the most important physical characteristics of a surface are its shock absorption, friction and ability to induce different levels of ball spin upon bouncing (Brody, 1987, 2003; Brody et al., 2002; Cross, 2001, 2002; Lees, 2003; Miller, 2006). Slow surfaces are characterised by a higher friction coefficient, decreasing horizontal speed and increasing bounce height, while fast surfaces are characterised by a lower friction coefficient, the ball gliding on the surface more easily, a smaller loss of speed in the horizontal direction and the ball bouncing at a smaller angle. The player has more time to prepare for the next stroke on a slow surface with a higher ball bounce and a lower horizontal speed. Conversely, on a fast surface, the ball shows a lower bounce and a smaller bounce angle, and the player can perceive it as fast, although the resulting ball speed can be the same in both cases (Brody, 1987).

The first and second serves do not depend directly on the surface of the court, instead being influenced by the player's strategy. The serve strategy is closely related to the probability of it being executed successfully (Barnett & Reid, 2012; Cross & Pollard, 2011). The most frequently used strategy is to risk more during the first serve with a higher ball speed, and risk less during the second serve (Pollard & Pollard, 2007). However, players do not use only the fastest variants of the flat serve for the first serve during a match, instead employing variants of ball spin that slightly reduce the maximum speed of the first serve. Other significant factors influencing the strategy of the serve include the match situation at a given moment, the player's strengths and exhaustion level, and environmental conditions such as the court surface and weather (Barnett & Reid, 2012; O'Donoghue & Ingram, 2001).

The association between the court surface and the serve speed in real situations has not been studied previously. There is a general view that the serve is more important at Wimbledon (WIM) than at the other Grand Slam tournaments (GSTs) (Brown & O'Donoghue, 2008). We wanted to determine whether different court surfaces influence player strategies in terms of the serve speed.

The aim of this study was to determine whether the serve speed at GST matches vary with the court surface. We hypothesized that the court surface does not affect the serve speed. The alternative hypothesis was based on the assumption that players' experiences with how the ball bounces on different court surfaces can influence their strategies of serve execution and therefore also the serve speeds.

2. Methods

2.1. *Participants*

The men and women participating in the singles matches at four GSTs in 2008, 2012 and 2016 were the subjects of this research. The participants at these tournaments were the world's best players (as listed in the top 100) and the best players in the qualifying matches. The number of players included in this study depended on the availability of complete serve-speed data on the websites of the tournaments, and it ranged between 72 and 92 for men and between 70 and 98 for women. The sets of players participating in various GSTs consist partly of the same players and partly of new players who have entered to a tournament based on qualifying tournaments or due to the process used for official ATP and WTA rankings. The sets of players who participated at all four GSTs in a given year were selected simultaneously. This group contained from 20 to 30 players.

The research design was approved by the Institutional Review Board of the Diagnostic Center of Human Movement at the University of Ostrava.

2.2. *Data collection*

The serve-speed data as measured using radar guns were obtained from the individual overall match statistics available on the official web pages of the four GSTs: Australian Open (AUO), French Open (FRO), WIM and US Open (USO). The surfaces at these GSTs were very different. In addition to the two extreme types of surface – sand (slow) at FRO and grass (fast) at WIM – there are artificial surfaces at AUO and USO that may be characterised as medium or medium fast. The match statistics provided the following three serve-speed metrics:

1. The speed of the fastest serve (FS), which is the highest serve speed achieved by a player in a given match.
2. The average speed of the first serve in a given match (S1).
3. The average speed of the second serve in a given match (S2).

Where possible, the serve-speed data for a player were obtained from his or her first-round match; otherwise they were taken from the first match for which full serve statistics were available. Since some of the players were eliminated from the tournament in the first round without playing on the courts where the serve speed was measured, these players were reduced from the total number. The total number of players included in this study has always been less than the 128 players who played in the first round of a tournament. Therefore, players who participated in the second round, without available first-round serve speed data, were assigned the serve speed data from the second round.

2.3. *Statistics*

The normality of the data was tested using the Lilliefors modification of the Kolmogorov-Smirnov test for all 72 data sets of the players (i.e. 3 periods of GSTs,

4 GSTs during each period, 3 categories of the serve speed, both genders), which revealed that the data were consistent with a normal distribution. Standard statistical calculations were performed using STATISTICA (version 12, StatSoft, Tulsa, OK). To identify significant differences between the individual tournaments in the same year, the statistical analysis was performed using a mixed linear model procedure while allowing for repeated measurements and missing data (NCSS 2007, Keysville, UT). Repeated-measures ANOVA was used to test for differences between `GSTs for the set of players who participated in all four GSTs in a given year. Bonferroni adjustment of the probability values was applied in multiple comparisons. The probability cut-off for statistical significance was $p < 0.05$.

3. Results

3.1. *Men*

In 2008 and 2012, there were either only marginal or no significant differences in FS between individual GSTs (the maximum difference was 2% of the highest value) (Table 1). Only in 2016 was there a significant difference in FS, which was lower at FRO than at the other GSTs. A statistical analysis of differences between the GSTs with respect to S1 and S2 in all three examined years gave a similar result. S1 and S2 were always significantly higher at WIM than at the other GSTs, with the exception of S1 in 2016.

3.2. *Women*

The statistically significant differences between serve speeds at individual GSTs among female players were similar to those among male players (Table 2). The differences between FS at individual tournaments are mostly statistically insignificant, with the exception of AUO in 2012 and FRO in 2016. As for the men, S1 and S2 were highest at WIM in all three years. The number of statistically significant differences between S1 at WIM and at the other GSTs was lower for women than for men.

We also investigated differences among the sets of players who participated in all four GSTs (n = 20–30) in a given year. This mostly involved players who had particularly high world rankings. The results of the repeated-measures ANOVA were practically identical to those in the analysis of all sets of players presented in Tables 1 and 2. An example of such an analysis is shown graphically in Figure 1.

4. Discussion

This study investigated the world's top tennis players at the four most prestigious world tournaments that are characterised by marked differences in playing surfaces. The two extreme types of surfaces at GSTs (slow [sand] at FRO and fast [grass] at WIM) are complemented by two types of artificial surfaces (at AUO and USO) that are – in terms of the physical properties of the contact of the ball with the surface – intermediate between these two extremes (International Tennis Federation, 2007). From the long-term perspective, the sand and grass surfaces may be considered as standards, while the

Table 1. Differences in the serve speed of Grand Slam tournaments, men.

		2008					2012					2016				
Serve speed	GST	Mean	SD	AUO	FRO	WIM	Mean	SD	AUO	FRO	WIM	Mean	SD	AUO	FRO	WIM
FS(km/h)	AUO	205.94	8.18				202.21	10.59				205.47	10.66			
	FRO	208.16	8.80				203.95	9.14				201.20	9.30	**		
	WIM	206.10	9.04				205.65	9.08				205.45	10.09		**	
	USO	206.61	9.88				206.62	10.70	*			206.50	10.36		**	
S1(km/h)	AUO	183.58	8.97				179.14	10.76				184.69	9.82			
	FRO	184.19	9.90				181.22	10.33				180.27	9.58	*		
	WIM	189.87	8.57	**	**		185.19	8.90	**	*		185.69	8.84		**	
	USO	181.69	10.26			**	182.26	10.86			*	183.28	10.34		*	
S2(km/h)	AUO	148.54	7.34				144.20	11.19				151.45	11.44			
	FRO	148.71	8.07				147.51	9.04				146.59	10.33			
	WIM	158.71	9.89	**	**		153.51	10.52	**	**		155.62	10.14	*	**	
	USO	148.79	9.58			**	149.02	10.30			*	148.07	11.65			**

Note: FS: The fastest serve in the match; S1: The average speed of the first serve in a given match; S2: The average speed of the second serve in a given match; GST: Grand Slam tournament; AUO: Australia Open; FRO: French Open; WIM: Wimbledon; USO: US Open; (* $p < 0.05$; ** $p < 0.01$).

Table 2. Differences in the serve speed of Grand Slam tournaments, women.

		2008					2012					2016				
Serve speed	GST	Mean ± SD		AUO	FRO	WIM	Mean ± SD		AUO	FRO	WIM	Mean ± SD		AUO	FRO	WIM
FS(km/h)	AUO	171.92	9.30				168.91	7.86				173.61	11.24			
	FRO	175.74	8.44				173.17	9.97	*			171.31	9.90			
	WIM	173.84	8.50				172.38	9.33				174.53	7.78		*	
	USO	173.80	8.85				174.54	11.01	**			174.32	9.57		*	
S1(km/h)	AUO	154.91	9.31				152.17	8.97				157.88	10.94			
	FRO	158.06	9.45				155.23	9.67				155.17	9.14			
	WIM	160.71	8.58	**			157.03	8.76	*			159.19	7.28		**	
	USO	155.15	9.21			**	156.04	10.09				156.45	9.72			*
S2(km/h)	AUO	132.15	8.66				126.72	8.08				131.64	9.40			
	FRO	132.32	8.45				130.05	8.15				129.90	7.83			
	WIM	138.01	8.75	**	**		133.04	8.79	**	*		135.92	8.53	**	*	
	USO	129.32	7.97			**	130.11	7.87			*	130.47	8.27			**

Note: FS: The fastest serve in the match; S1: The average speed of the first serve in a given match; S2: The average speed ofthe second serve in a given match; GST: Grand Slam tournament; AUO: Australia Open; FRO: French Open; WIM: Wimbledon; USO: US Open; (* $p < 0.05$; ** $p < 0.01$).

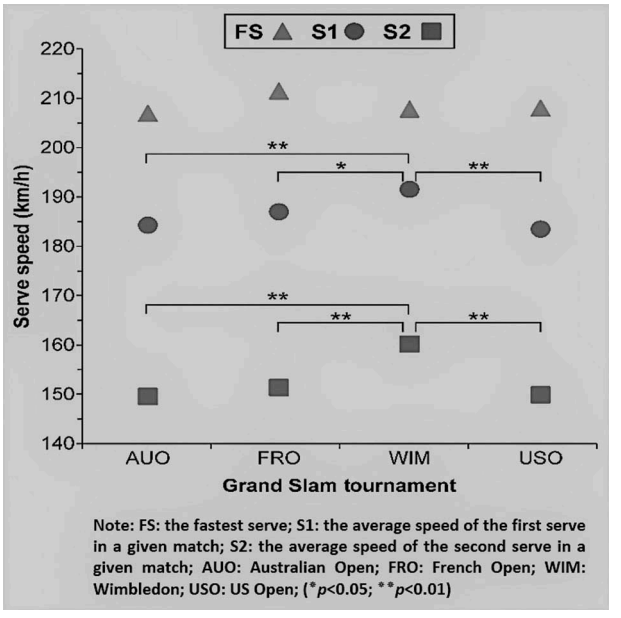

Figure 1. The serve speed at Grand Slam tournaments in 2008 (Men, $n = 28$).

Note: FS: The fastest serve in the match; S1: The average speed of the first serve in a given match; S2: The average speed of the second serve in a given match; GST: Grand Slam tournament; AUO: Australia Open; FRO: French Open; WIM: Wimbledon; USO: US Open; (* $p < 0.05$; ** $p < 0.01$).

physical properties of the artificial surfaces used at the other GSTs may differ slightly between different years depending on the variations in the characteristics of new artificial surfaces.

This study found only minor differences in FS at the individual tournaments, with it ranging from 96.6% to 100% for men and from 96.7% to 100% for women in individual years when the highest FS was normalized to 100%. FS was highest at FRO in 2008 for both men and women, and lowest at FRO in 2016 for men and at AUO in 2012 for women. It was not possible to derive a relationship between FS and the court surface due to the small number of statistically significant differences between the tournaments. The highest and lowest FS values may also be subject to arbitrary influences (e.g. weather conditions of sun, wind and temperature) or the use of different systems to measure or calibrate the serve speed. This is supported by the values of FS, S1 and S2 all being lowest at AUO in 2012 and at FRO in 2016 for both men and women.

S1 represents the average speed of the first serve throughout a match. If most of the first serves are focused on attaining a high speed, the average value of S1 increases, whereas a focus on a higher number of variants of ball spin would decrease the S1. The value of S1 may already reflect the strategy of the first serve. The present study found that in all three examined years, S1 was highest at WIM in both men and women. Most of the differences in S1 between WIM and the other GSTs were statistically significant: in 10 out of 12 tests for men, and in 5 out of 12 test for women (Tables 1 and 2). There were no significant differences between the S1 values measured at the other GSTs. From these results it is possible to conclude that the players at WIM (on the fast grass court

surface) mostly strive to obtain a higher speed of the first serve during the match relative to playing at the other GSTs with different court surfaces. This is probably associated with the experience of the players with the bounce of the ball on the fast grass surface, which reduces the loss of speed in the horizontal direction only minimally and for which a lower bounce angle is typical; it also shortens the time of contact when the ball is returned (Brody, 1987, 2003; Brody et al., 2002; Cross, 2001, 2002; Lees, 2003; Miller, 2006; O'Donoghue & Ballantyne, 2004). Higher service speeds throughout the game have been indirectly verified by the research results (Takahashi et al., 2006) that have found the shortest time between service and return on WIM on the grass surface compared to other GSTs (0.71 s on WIM grass vs 0.73 s on hard surface and 0.91 s on clay).

In the case of the second serve, the dominant strategy is to achieve a high probability that the ball will fall within the service box (Pollard & Pollard, 2007). The second serve is therefore typified by a lower ball speed and more variable levels of ball spin, which extends the serve window and increases the probability that the ball will land in the service box (Brody, 1987, 2006). S2 was significantly higher at WIM for both men and women in all three examined years (Tables 1 and 2). The significant differences have clearly demonstrated that the players' strategy involved making the second serve higher on the fast grass surface than on the other surfaces, despite this increasing the risk of an unsuccessful serve. The tendency to serve at a higher speed on the grass surface at WIM also during the second service is related to players wanting to make use of the specific physical properties of the grass surface at the ball's impact making it more difficult for the other player to return the service (Brody, 1987, 2003; Brody et al., 2002; O'Donoghue & Ballantyne, 2004). The greater importance of serve speed on the grass surface at WIM is further supported by Hughes and Clarke (1995) establishing that the proportion of successful returns was 11% lower on grass than on an artificial surface. This statement is supported by the results of the study (Collinson & Hughes, 2002) that found women have greater difficulty returning serves on fast surfaces.

4.1. *Limitations of the study*

Not all of the participants at the tournaments were included in this study since some of the first rounds were played on courts that did not have a system for measuring the serve speed. The sets of players (n = 70–90) included in the statistical analyses consisted of the world's top players who proceeded to the subsequent tournament rounds, and these populations may be considered a selection of the best tennis players currently in the world at the given tournament.

One limitation of the study was that the serve speeds were measured using radar guns. Deviations of the ball's trajectory from the radar direction cause errors in the measured speeds, which may be as high as 2.6% when the angle of declination is 13° (Vaverka & Cernošek, 2013). In most cases the measuring error is small and, given the high serve speed, can be considered negligible. Other possible accuracy limitations in the measured serve speeds are the calibration or technical parameters of the measuring system, which might be responsible for the hard-to-explain very low values of FS, S1 and S2 measured at FRO in 2016 or AUO in 2012 in both men and women. The input serve-speed data measured in the first or second round of a

tournament may constitute another limitation. It is known that the serve speeds measured by individual in the course of tournaments vary significantly (Vaverka & Cernošek, 2013). However, despite these limitations, the results obtained in the study – which included data for the world's top players measured in real matches and at top-level tournaments – may be considered valid.

One of the factors limiting service speed may be the different properties of tennis balls. On GSTs we also encounter different court surfaces with different brands of balls (Wilson for hard surfaces AUO and USO, Babolat for FRO and Slazenger for WIM) and with different material of the ball surface for men (extra-duty felt ball) and women (regular-duty felt ball). The size and pressure of the balls are the same for both men and women (Newcomb, 2017). Tolerance in the size and weight of the balls used in the official ATP and WTA tournaments is fairly high (ITF, 2007: the diameter hovering between 6.58 and 6.86 cm and weighing between 55.99 and 59.39 g) and the differences between the extreme values of these tolerance bands are for the ball diameter 0.28 cm and for the ball weight 3.4 g. The balls used in the WIM (Slazenger) have a 13% greater diameter than in the other GSTs (Miller, 2016) and are closest to the Type 3 balls of the ITF (ITF, 2007). In terms of study limits, it is essential to note that different ball diameters do not affect the initial service speed, but their size affects its accuracy (Blackwell & Knudson, 2002). Cooke and Davey (2011) indicate that for type 3 balls the service accuracy is higher by 19%. From this point of view, the comparison of the initial service speed on individual GSTs is comparable to different GSTs, men and women, and does not depend on the size and weight of the balls. The speed of service can also be affected by the interaction between the tension strings and the ball type. Some players use different tension strings with regard to the type of balls in that tournament (Miller, 2016). These limits depend on the player's individual approach to the physical characteristics of the tennis racket he is using.

5. Conclusions

FS varied irregularly between the GSTs tournaments in both men and women, but the differences between tournaments were not statistically significant (except at FRO in 2008 and AUO in 2012). S1 was highest at WIM (on grass) for both men and women and in all three observed years, with most of the differences being statistically significant. Similarly, to S1, S2 for both men and women was highest at WIM in all three years, with all of the differences between WIM and the other GSTs being statistically significant. At the other three GSTs (AUO, FRO and USO) involving various court surfaces, the values of FS, S1 and S2 varied irregularly, but no significant differences between these tournaments were confirmed. The results showed that the tennis court surface affected the serve-speed strategy only in the case of the grass surface at WIM for S1 and S2 for both sexes and all observations during 2008–2016. The maximum FS service speed is not affected by the different surfaces of the GSTs courts. The influence of the court surface is reflected only in WIM, where higher S1 and S2 indicate the player's strategy to serve during a match with a higher number services of higher speeds on both 1st and 2nd service compared to other GSTs.

Disclosure statement

No potential conflict of interest was reported by the authors.

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