Matjaž Stare[1]
Uroš Žibrat[2]
Aleš Filipčič[3]

STROKE EFFECTIVNESS IN PROFESSIONAL AND JUNIOR TENNIS

UČINKOVITOST UDARCEV V PROFESIONALNEM IN MLADINSKEM TENISU

ABSTRACT

With the SAGIT/TENNIS system, we gathered tennis game data on the effectiveness of the serve, return of the serve and the base line game of seven male professional, eleven male and ten female junior tennis players. The purpose of the study was to find out whether there are any differences between groups of players in regards to the outcome and effectiveness of strokes in different game situations. A one-way ANOVA and the Tukey post-hoc test was employed to assign specific differences between the groups. On average, matches lasted for one hour; duration of the rallies was on average 4.4 to 7.3 seconds; and in each rally, there were 3 to 5.3 shots performed. The percentage of the active part of the game lasted from 18 % to 27.6 %, with more than half of the points ending before 5 seconds. Professional tennis players achieved a higher number of aces with their first serve. Female junior (6 %) and professional tennis players (7.6 %) had a significantly higher percentage of successful second serves and were more successful in executing returns on the second serve. Professional tennis players played much more offensively on the base line, which was evident from their significantly lower percentage of successful shots; in addition, they used the backhand slice more frequently to change the rhythm of the game. The applied system enables the identification of game patterns and situations, and thus more targeted planning in training.

Key words: tennis players, match notation, performance analysis

[1]self-employed tennis coach, [2]Agricultural Institute of Slovenia, [3]University of Ljubljana, Faculty of Sport

Corresponding author:
Dr. Aleš Filipčič
University of Ljubljana, Faculty of sport
Gortanova 22, 1000 Ljubljana
E-mail: ales.filipcic@fsp.uni-lj.si
Mobile phone: +386 41 704 876

IZVLEČEK

S sistemom SAGIT/TENNIS smo za sedem profesionalnih igralcev, enajst mladih igralcev in deset teniških igralk zbrali podatke o igralni učinkovitosti servisa, reterna in udarcev na osnovni črti. Z enosmerno analizo variance in Tukey testom smo želeli ugotoviti, ali obstajajo razlike med skupinami igralcev z vidika učinkovitosti v različnih igralnih situacijah. Tekme so v povprečju trajale 1 uro, točke od 4,4 do 7,3 sek in v vsaki točki je bilo izvedenih od 3 do 5,3 udarcev. Delež aktivnega dela tekme je znašal od 18 % do 27,6 % in več kot polovica točk se je končala znotraj 5 sek. Profesionalni teniški igralci so dosegli višje število asov s prvim servisom. Mlade igralke (6 %) in profesionalni teniški igralci (7,6 %) so imeli značilno višji odstotek uspešnih drugih servisov in so bolj uspešni pri izvajanju bekend reterna na drugi servis. Profesionalni teniški igralci na osnovni črti igrajo bistveno bolj napadalno, kar se kaže v značilno nižjem odstotku uspešnih udarcev. Pogosteje uporabljajo bekend slajz udarec, s katerim spreminjajo ritem igre. Uporabljen sistem omogoča prepoznavanje igralnih vzorcev in situacij in s tem bolj usmerjeno načrtovanje treninga.

Ključne besede: teniški igralci, notacija tekme, analiza učinkovitosti

INTRODUCTION

Game characteristics

Tennis is an open skill sport in which players constantly make decisions related to the positioning and types of shots to be played (O'Donoghue & Ingram, 2001). Notational (Downey, 1992) and performance analysis (Hughes & Bartlett, 2002; Hughes & Clarke, 1995) are methods that analyse both dynamic and complex situations in a sport. Match analysis is an area of sports science and describes the performance in a particular match. A player's performance can be defined with performance success on national or international ranking lists, or through performance indicators that are recorded or monitored during the tennis match. As Hughes, Hughes and Behan (2007) have identified, we can record tactical, technical, movement and performance indicators, with which we can create databases and modelling.

In this study we will focus on tactical performance indicators, which accompany performance success of tennis players from the standpoint of stroke effectiveness. Studies which dealt with performance indicators analysed serve performance (O'Donoghue & Ingram; 2000; Furlong, 1995; Hughes & Clarke, 1995; O'Donoghue & Ballantyne, 2004; O'Donoghue & Ingram, 2001; Hernández-Davo, Urbán, Sarabia, Juan-Recio, & Moreno, 2014; Gillet, Leroy, Thouvarecq, & Stein, 2009); effectiveness of the return of serve (Gillet, et al., 2009; Hizan, Whipp, & Reid, 2010); base line game characteristics (Hughes & Clarke, 1995; Carvalho et al., 2013; Johnson, McHugh, Wood, & Kibler, 2006; Martínez-Gallego et al., 2013; Unierzyski & Wieczorek, 2004; Vergauwen, Spaepen, Lefevre, & Hespel, 1998; Vergauwen, Madou, & Behets, 2004; Morante & Brotherhood, 2005); correlation of serve; return of serve and net game (Hughes & Franks, 2004; Brown & O'Donoghue, 2008); and, finally, the strategies of how to balance the number of errors in the game (Brody, 2006).

There are not many studies that have considered all types of strokes through an analysis of tennis matches. The majority of studies have addressed the efficiency of the serve and of the return of serve. Vergauwen, et al., (1998) found in laboratory conditions that international level tennis players serve and return faster and more precisely than national level players. They are also more successful in neutral rallies and play forehand and backhand faster. Comprehensive load analysis of tennis players in three Grand Slam (GS) tournaments (US Open, French Open, Wimbledon) was conducted by Johnson and McHugh (2006), who found that tennis players on hard courts performed on average 17.9 shots per game; on clay 21; and on grass, 16 shots, when serving. For the return of serve, tennis players on average hit 12.2 shots on hard courts, 14.8 on clay, and 10.4 on grass. Detailed data on the number of shots on hard courts show that tennis players in each game performed 2 forehand and 3.2 backhand returns; 3.2 forehands and 2.5 backhand topspins; 0.2 forehand and 0.9 backhand slices; 0.04 forehand and 0.09 backhand volleys. Fernandez-Fernandez, Sanz-Rivas, Fernandez-Garcia and Mendez-Villanueva (2008) did not detect any significant differences in physiological parameters in the serving and receiving games of female tennis players.

Katic, Milat, Zagorac and Djurovic (2011) found that game winners on grass achieved significantly more aces, less double faults and unforced errors, which is not the case in Grand Slam tournaments on clay. On clay, men performed 52.7 % forehands and women, 49.3 %; while on grass, the share of forehands is 41.4 % for men, and 48.7 % for women. On both surfaces, women made more double faults and achieved a lower percentage of aces. Men achieved less points from

their opponent's unforced errors on both surfaces (Men/Clay = 70.59 %; Women/Clay = 72.75 %; Men/Grass = 61.23 %; and Women/Grass = 72.91 %); and on grass, they achieved a higher percentage of net points than women (Verlinden et al., 2004). The analysis of net approaches on U.S. Open showed that the distribution of performance indicators is normal for an individual player's performance, but that is certainly not the case when comparing more players (O'Donoghue, 2006). Djurovic, Lozovina, and Pavicic (2009) detected that on hard court, the Grand Slam tournament factors that have the greatest impact on the player who wins a game are: the total number of break points, the serve speed and the lowest percentage of unforced errors and double faults. Martínez-Gallego et al., (2013) using the SAGIT system, found that game losers cover less distance, move faster and spend more time in the defensive court zone, which is due to the fact that game winners play a more aggressive game and spend more time near the base line.

Video motion tracking in sports is an established method for capturing and analysing the activities of athletes in basketball, handball, soccer and squash. In tennis, Petkovic, Jonker, and Zivkovic (2001) presented the possibility of recognizing different classes of tennis strokes using automatic learning capability. Filipcic, Pers and Klevisar (2006) established the scope of movement of junior tennis players during the game with the help of the SAGIT system. Hurnik, Unierzyski and O'Donohue (2008) verified the potential in the reliability of a computerised notational analysis system for recording the bounce placement of tennis balls on the court. Martínez-Gallego, et al. (2013) have not detected any significant differences between the winners and losers in ATP tournaments in offensive and defensive zone movement and in the application of cross court and down-the-line shots. Terroba, Kosters, Varona, and Manresa-Yee (2013) transcoded the television footage of tennis matches into discrete temporal data and set the optimal winning strategy for each player.

Based on data, which was gathered by video analysis of tennis matches, we compared three quality groups of male and female players in this study: Association of Tennis Professional, or ATP, players; boys 14&under; and girls 14&under. The first aim of the study was to determine the performance success of male and female tennis players in three game situations: serve, return of serve and base line game. We wanted to find out whether there are any differences between groups of players from the standpoint of the outcomes and effectiveness of strokes in different game situations.

Sample of matches and participants

The institutional Human Ethics Committee approved the experimental design and protocol prior to data collection. Matches (n = 15) were recorded at the national championship for boys (B14) and girls 14&under (G14) and tournament for professional tennis players (ATP) on Rebund Ace GS surface in an indoor tennis facility. All the participants (n = 28) were considered as highly trained and ranked on national (14&under players) or professional ranking list (male ATP players).

Table 1: Mean (±SD, range) age, height, weight, national and professional ranking.

Group	N	Age (years)	Height (cm)	Mass (kg)	Ranking (mean, min, max)
B14	11	13.8 ±0.7	176 ±7.5	67.6 ±11	7 (1 – 17) *
G14	10	14.1 ±0.5	162.2 ±8.4	52.1 ±4.4	4.6 (1 – 18) *
ATP	7	18.3 ±4.7	181.4 ±9.5	75 ±7.7	380 (121 – 1020) **

Note: * national ranking, ** ATP ranking.

Procedure

During the tournament all matches were recorded with fixed SVHS video cameras (Ultrak CCD Color KC 7501 CP) with the frequency of capturing input images at 25 Hz. Each camera was fastened to the ceiling; therefore, its wide-angled lens (Ultrak KL 28141s 2.8 mm, Japan) covered the entire half of the court. The video recordings were digitized using the Video DC30* video digitizer hardware (Miro, Germany) with a resolution of 384x576 at 2 MB s2 data rate, while processing was carried out at a resolution of 384 x 288 pixels. The accuracy of the SAGIT system was verified in the study Filipcic, Filipcic and Pers (2009) and Vuckovic, Pers, James and Hughes (2010).

The digital images were processed with the SAGIT/TENNIS tracking system using a computer vision method (Pers, Bon, Kovacic, Sibila, & Dezman, 2002; Vuckovic, et al., 2010). The conversion into numerical data was carried out in the following steps: (1) recording tennis matches; (2) re-recording and compression of the recordings into digital format; (3) calibration of the recordings (time and space calibration); (4) data processing with the SAGIT/TENNIS tracking system (notation of players movement, split step, strokes and outcomes and match and time characteristics)—and exporting into a data base; and (5) processing data with the statistical programme.

Using the SAGIT/TENNIS, we gathered data on time, game parameters and efficiency of strokes, divided into three game situations: serve, return of serve and base line and net game. Net game strokes (volley, drive volley, overhead smash) were not included in the study due to their low frequency, as is the case also in the study (Johnson, et al., 2006). Efficiency was by each stroke observed through four possible stroke outcomes: error in the net (EN), error in the out (EO), successful stroke (IN) and winner (WIN). Descriptive statistics (min, max, mean, ±SD) are reported for the measured variables. The 1-way analysis of variance (ANOVA) was used to determine the differences between stroke effectiveness in three game situations. The Tukey post-hoc test was employed to assign specific differences between male and female junior and male professional tennis players. The SPSS statistical software package (version 21, SPSS Inc., Chicago, IL, USA) was used for statistical calculations. The level of statistical significance was set at $p = 0.05$.

RESULTS

Matches of professional tennis players lasted the longest. They also played the highest number of rallies; however, they lasted, on average, only 4.4 seconds, and the players, on average, performed 3 strokes per rally. The active game time lasted only 18 % of the total match time, with 67.2 % points ending in less than 5 seconds. Less than 1 % of points lasted more than 20 seconds.

From the standpoint of time parameters, the matches of male and female junior tennis players had very similar characteristics. Matches, on average, lasted for one hour, and the duration of the rallies was on average 7.3 to 6.3 seconds. Also similar was the percentage of the active part of the game in comparison to the total duration of the match. More than half of the points ended in less than 5 seconds. On average, male tennis junior players performed a higher number of strokes than female junior tennis players; consequently, they also played more strokes per rally on average.

Table 2: Match and time parameters for male, female junior and professional tennis players.

Player's group	Matches played	Match duration (min)	Rallies	Rally duration (s)	Effective playing time (%)	Rallies ≤ 5 s	Rallies 5 – 10 s	Rallies 10-20 s	Rallies ≥ 20 s	Strokes in a match	Strokes in a rally
B14	6	65.4	145.2	7.3	27.6	51.5	22.8	19	6.7	768.7	5.3
G14	5	59.8	133.8	6.3	23.5	56.8	23.6	14.8	4.8	572.4	4.3
ATP	5	81.0	193	4.4	18	67.2	23.4	8.7	0.8	569.6	3.0

In the first game situation we analysed the efficiency of the first (1S) and second serves (2S); in the second, the efficiency of the forehand (1SF, 2SF) and backhand in the return of serve (1SB, 2SB) after the first and second serves; and in the third, the efficiency of topspin forehand, topspin backhand, the slice forehand and slice backhand. Descriptive statistics are presented in table 2.

Table 3: Differences between players' groups in first and second serve outcomes.

		Group	Min	Max	Mean	SD	F	p	B14	G14	ATP
1S	EN	B14	0.33%	3.32%	1.36%	0.01				0.06	0.46
		G14	1.09%	12.37%	3.69%	0.03	3.24	0.05	3.40		1.69
		ATP	0.46%	3.92%	2.52%	0.02			1.70	0.46	
	EO	B14	0.46%	4.43%	1.94%	0.01				0.20	0.05
		G14	0.54%	8.05%	3.30%	0.02	3.42	0.05	2.49		1.00
		ATP	0.92%	6.30%	3.85%	0.02			3.49	0.76	
	IN	B14	5.51%	11.16%	8.79%	0.02				0.30	0.58
		G14	5.75%	17.54%	10.82%	0.04	1.34	0.28	2.14		0.72
		ATP	6.10%	14.88%	10.14%	0.03			1.42	0.87	
	ACE	B14	0.00%	0.93%	0.23%	0.00				0.98	0.00 *
		G14	0.00%	2.29%	0.29%	0.01	13.02	0.00 *	0.30		6.40
		ATP	0.00%	2.74%	1.57%	0.01			6.70	0.00	
2S	EN	B14	0.00%	1.23%	0.42%	0.00				0.17	1.00
		G14	0.00%	1.72%	0.86%	0.01	2.47	0.10	2.64		2.74
		ATP	0.00%	1.39%	0.40%	0.00			0.10	0.15	
	EO	B14	0.00%	1.65%	0.53%	0.00				0.96	0.60
		G14	0.00%	1.61%	0.59%	0.00	0.75	0.48	0.38		1.75
		ATP	0.00%	0.79%	0.34%	0.00			1.37	0.44	
	IN	B14	1.27%	5.33%	3.44%	0.01				0.01 *	0.00 *
		G14	2.19%	8.90%	5.97%	0.02	15.76	0.03	4.76		2.99
		ATP	5.32%	9.46%	7.55%	0.01			7.75	0.11	
	ACE	B14	0.00%	0.30%	0.03%	0.00				0.49	0.79
		G14	0.00%	0.56%	0.11%	0.00	0.77	0.48	1.64		0.70
		ATP	0.00%	0.35%	0.07%	0.00			0.94	0.87	

Note: Min, Max, Mean - arithmetic mean for players' group and stroke outcomes, F - value, * $p<0.05$, Tukey's pairwise comparisons: Q below diagonal, p (same) above diagonal, * $p<0.05$.

Table 4: Differences between players' groups in the return of first and second serve outcomes for forehand and backhand strokes.

		Group	Min	Max	Mean	SD	F	p	B14	G14	ATP
1SF	EN	B14	0.19%	0.90%	0.47%	0.00				0.12	0.33
		G14	0.00%	2.82%	1.03%	0.01	2.54	0.10	2.92		0.87
		ATP	0.52%	1.22%	0.86%	0.00			2.05	0.81	
	EO	B14	0.19%	0.74%	0.42%	0.00				0.29	0.61
		G14	0.00%	2.26%	0.73%	0.01	1.36	0.27	2.17		0.81
		ATP	0.26%	1.46%	0.61%	0.00			1.35	0.83	
	IN	B14	0.94%	3.84%	2.16%	0.01				0.41	0.12
		G14	1.14%	5.08%	2.71%	0.01	2.24	0.13	1.83		1.08
		ATP	1.83%	4.16%	3.04%	0.01			2.91	0.73	
	WIN	B14	0.00%	0.93%	0.42%	0.00				0.95	0.96
		G14	0.00%	1.11%	0.37%	0.00	0.15	0.86	0.42		0.80
		ATP	0.00%	1.33%	0.47%	0.00			0.39	0.84	
1SB	EN	B14	0.24%	1.85%	0.97%	0.01				0.92	0.18
		G14	0.19%	3.23%	1.09%	0.01	2.53	0.10	0.57		3.15
		ATP	0.23%	0.73%	0.43%	0.00			2.59	0.08	
	EO	B14	0.49%	1.85%	1.23%	0.00				0.00 *	0.00 *
		G14	0.00%	1.13%	0.58%	0.00	10.44	0.00 *	5.05		0.55
		ATP	0.26%	1.22%	0.51%	0.00			5.60	0.92	
	IN	B14	1.02%	4.14%	2.93%	0.01		0.44		0.69	0.43
		G14	1.64%	8.47%	3.54%	0.02	0.86		1.18		0.61
		ATP	2.13%	7.66%	3.85%	0.02			1.78	0.90	
	WIN	B14	0.19%	1.39%	0.48%	0.00				0.56	1.00
		G14	0.00%	1.71%	0.71%	0.01	0.79	0.46	1.46		1.59
		ATP	0.00%	1.39%	0.46%	0.01			0.13	0.51	
2SF	EN	B14	0.00%	0.49%	0.29%	0.00				0.13	0.34
		G14	0.00%	1.09%	0.52%	0.00	2.42	0.11	2.84		0.80
		ATP	0.00%	0.91%	0.45%	0.00			2.04	0.84	
	EO	B14	0.00%	1.11%	0.39%	0.00				0.92	0.93
		G14	0.00%	2.30%	0.48%	0.01	0.11	0.90	0.57		0.06
		ATP	0.00%	1.22%	0.47%	0.00			0.51	1.00	
	IN	B14	0.39%	2.37%	1.13%	0.01				0.29	0.00 *
		G14	0.57%	3.14%	1.63%	0.01	9.79	0.00 *	2.17		4.12
		ATP	1.59%	3.72%	2.58%	0.01			6.29	0.02	
	WIN	B14	0.00%	0.66%	0.30%	0.00				0.84	0.01 *
		G14	0.00%	1.09%	0.22%	0.00	7.23	0.00 *	0.80		5.27
		ATP	0.26%	1.15%	0.73%	0.00			4.47	0.00	
2SB	EN	B14	0.00%	0.74%	0.13%	0.00				0.21	0.37
		G14	0.00%	0.82%	0.33%	0.00	1.91	0.17	2.47		0.54
		ATP	0.00%	0.62%	0.29%	0.00			1.93	0.92	
	EO	B14	0.00%	0.93%	0.29%	0.00				0.66	1.00
		G14	0.00%	1.69%	0.46%	0.01	0.57	0.57	1.24		1.35
		ATP	0.00%	0.73%	0.27%	0.00			0.11	0.61	
	IN	B14	0.19%	1.67%	0.89%	0.00				0.02 *	0.00 *
		G14	0.57%	5.00%	2.05%	0.01	9.64	0.00 *	4.11		1.79
		ATP	1.33%	3.98%	2.55%	0.01			5.90	0.43	
	WIN	B14	0.00%	0.60%	0.19%	0.00				0.83	0.83
		G14	0.00%	1.11%	0.27%	0.00	0.25	0.78	0.82		0.01
		ATP	0.00%	0.69%	0.27%	0.00			0.83	1.00	

Note: Min, Max, Mean - arithmetic mean for players' group and stroke outcomes, F - value, * $p<0.05$, Tukey's pairwise comparisons: Q below diagonal, p (same) above diagonal, * $p<0.05$.

The results of the ANOVA and the Tukey post-hoc tests (Table 3) show that players in the three groups significantly differ in the percentage of achieved aces. Professional tennis players achieved a higher number of aces with their first serve. Female junior and professional tennis players have a significantly higher percentage of successful second serves than male junior tennis players.

Players in the three groups differed significantly (Table 4) in their percentage of backhand returns on the first serve (error out), forehand returns on the second serve (in, winner) and backhand returns on the second serve (in). Professional tennis players are more successful in executing forehand returns on their second serve and achieve more winners with this stroke. Female and professional tennis players made significantly less net errors with backhand returns of serve on their opponent's first serve and were significantly more effective in executing backhand returns on the second serve.

On the base line, players of our three groups (Table 5) significantly differed in their percentage of net errors and successful forehand topspins, forehand slices (error net, error out and in), backhand topspins (winning) and backhand slices (error net, out, in). Female junior tennis players

Table 5: Differences between players' groups in forehand topsin and slice outcomes.

FTS	EN	B14	1.03%	6.35%	3.10%	0.02				0.04 *	0.21
		G14	0.56%	2.69%	1.54%	0.01	3.99	0.03 *	3.69		1.24
		ATP	1.05%	3.94%	2.07%	0.01			2.45	0.66	
	EO	B14	1.45%	5.94%	3.72%	0.01				0.21	0.08
		G14	1.09%	3.80%	2.76%	0.01	2.98	0.07	2.44		0.75
		ATP	0.61%	4.14%	2.47%	0.01			3.19	0.86	
	IN	B14	13.48%	31.09%	23.25%	0.05				0.95	0.01 *
		G14	15.71%	30.36%	22.55%	0.06	5.05	0.01	0.41		3.85
		ATP	9.91%	23.87%	15.96%	0.05			4.26	0.03	
	WIN	B14	0.37%	4.63%	2.56%	0.01				0.20	0.44
		G14	0.00%	4.57%	1.49%	0.02	1.84	0.18	2.48		0.73
		ATP	0.79%	3.39%	1.81%	0.01			1.75	0.86	
FSL	EN	B14	0.19%	5.35%	1.83%	0.02				0.00 *	0.04 *
		G14	0.00%	0.57%	0.08%	0.00	7.96	0.00 *	5.14		1.44
		ATP	0.00%	2.17%	0.57%	0.01			3.70	0.57	
	EO	B14	0.19%	3.24%	1.69%	0.01				0.00 *	0.00 *
		G14	0.00%	0.55%	0.07%	0.00	14.22	0.00 *	6.75		1.49
		ATP	0.00%	1.57%	0.43%	0.01			5.26	0.55	
	IN	B14	0.03%	1.66%	0.09%	0.02				0.00 *	0.00 *
		G14	0.00%	1.11%	0.50%	0.00	16.91	0.02 *	0.69		0.41
		ATP	0.45%	1.83%	0.97%	0.01			0.65	0.96	
	WIN	B14	0.00%	0.29%	0.06%	0.00				0.96	
		G14	0.00%	0.57%	0.06%	0.00	0.00	0.96	0.07		
		ATP	0.00%	0.00%	0.00%	0.00					

Note: Min, Max, Mean - arithmetic mean for players' group and stroke outcomes, F - value, * p<0.05, Tukey's pairwise comparisons: Q below diagonal, p (same) above diagonal, * p<0.05.

Table 6: Differences between players' groups in backhand topsin and slice outcomes.

		Group	Min	Max	Mean	SD	F	p	B14	G14	ATP
BTS	EN	B14	0.21%	7.01%	2.41%	0.02				0.69	0.95
		G14	0.00%	4.60%	1.77%	0.02	0.67	0.52			1.61
		ATP	0.73%	4.53%	2.66%	0.02			1.17	0.50	
	EO	B14	0.93%	5.90%	2.62%	0.02			0.39	0.78	0.96
		G14	1.09%	4.60%	2.14%	0.01	0.45	0.64			1.33
		ATP	1.04%	7.32%	2.82%	0.02			0.94	0.62	
	IN	B14	10.04%	26.11%	17.51%	0.05				0.76	0.25
		G14	7.60%	24.86%	19.19%	0.06	2.60	0.09	1.00		3.32
		ATP	7.66%	18.33%	13.60%	0.04			2.32	0.07	
	WIN	B14	0.19%	2.93%	1.44%	0.01				0.03 *	0.64
		G14	0.00%	1.09%	0.34%	0.00	7.16	0.00 *			5.21
		ATP	0.79%	3.34%	1.80%	0.01			3.93	0.00	
BSL	EN	B14	0.00%	1.14%	0.38%	0.00			4.62	0.94	0.01
		G14	0.00%	1.08%	0.28%	0.00	7.08	0.00			5.08
		ATP	0.35%	3.89%	1.34%	0.01			0.46	0.00	
	EO	B14	0.00%	1.15%	0.37%	0.00				0.42	0.02 *
		G14	0.00%	0.56%	0.13%	0.00	8.10	0.00 *			5.87
		ATP	0.26%	1.86%	0.89%	0.01			1.82	0.00	
	IN	B14	0.00%	3.69%	1.39%	0.01				0.92	0.00 *
		G14	0.00%	3.98%	1.75%	0.01	17.86	0.01 *	0.55		0.74
		ATP	1.00%	10.40%	6.60%	0.03			0.79	0.00	
	WIN	B14	0.00%	0.21%	0.02%	0.00				0.81	0.05
		G14	0.00%	0.56%	0.11%	0.00	3.17	0.06			2.65
		ATP	0.00%	1.52%	0.40%	0.01			0.88	0.17	

Note: Min, Max, Mean - arithmetic mean for players' group and stroke outcomes, F - value, * p<0.05, Tukey's pairwise comparisons: Q below diagonal, p (same) above diagonal, * p<0.05.

had a significantly lower percentage of net errors with the forehand topspin. As for professional tennis players, they had a lower percentage of the same shot executed into the court. Female junior tennis players had a lower percentage of backhand topspin wins than the other two groups of players. In the efficiency of their forehand slice, male junior tennis players (Table 6) differed significantly in net and out errors and in successfully executed shots, while in the execution of the backhand slice, professional tennis players differed significantly from the other two groups in their percentage of successful strokes, errors in net and out.

DISCUSSION

Notation of tennis matches allows a deeper insight into time and game parameters. The time statistics of professional tennis players are comparable to the measurements of (Fernandez-

Fernandez, et al., 2008) female players on the same playing surface (rally duration = 7.2. strokes per rally = 2.5, effective playing time = 21 %, rallies ≤ 6 s = 51 %).

There are fewer studies that have analysed the time and game parameters of junior tennis players. Torres-Luque, Cabello-Manrique, Hernández-García and Garatachea (2011) analysed 16-year-old male and female players, where on average, junior tennis players on hard court played 208 rallies per match. In 9 seconds, they played 5.2 strokes on average, and their effective playing time amounted to 31.5 %. The duration of the point and number of strokes used are to a great extent correlated with ball flight characteristics: with the direction, depth, height, rotation and speed of the ball. More indirect influences include: the match duration, the number of rallies, the total number of strokes, and the effective playing and resting time (an area in which professional tennis players differ from junior players).

Professional tennis players, as expected, achieved a significantly higher number of aces than junior players; compared to other studies, however, (O'Donoghue & Ingram, 2001; Katic, et al., 2011; Cross & Pollard, 2011) the values were significantly lower. In the mentioned studies, not all of the strokes were analysed, namely just the first and the final stroke; while in our study, all of the strokes performed in a match were analysed. Professional tennis players used their technical competency to perform the serve; they were also in optimal physical condition and had the ability to disguise the tactical intention, which enabled them to serve seven aces per match on average. As researchers have already discovered (O'Donoghue & Ingram, 2001), the efficiency of the serve is also influenced by the speed of playing surface.

We wanted to also explore from the viewpoint of a tennis coach whether players differed, by gender and ability group, in the type of errors (net, out), where the belief is, that the net error is "worse" than the out error. In this regard, professional and female junior tennis players differed significantly in the efficiency of their backhand return on their first and second serves. The efficiency of their return of serve was influenced by three factors: perceptual abilities (Williams, Ward, Smeeton, & Allen, 2004; Williams, Ford, Eccles, & Ward, 2010); anticipation (Hurnik, et al., 2008); and technical skills (Elliott, Reid, & Crespo, 2003). Because they have more experience and despite their opponent's faster serves, professional tennis players are capable of putting a higher percentage of serves in. These players more easily resolve game situations, where they need to adapt to the direction, speed and rotation of the serve. Professional tennis players have a clear tactical intention to take initiative in the game after the second serve, as witnessed by a significantly higher percentage of forehand return winners on their second serve. On the other hand, as Johnson, et al. (2006) identify, the server more frequently wants to direct their second serve to the opponent's backhand. Reid, McMurtrie and Crespo (2010) conclude that there is a strong association between the winning percentage of the first and second serve and the return on first and second serve.

The base line game highlights efficiency, along with the before mentioned ball characteristics, tactical strategy and shot selection. Female junior players, due to the trajectory of higher ball flight from their forehand topspin, made significantly less net errors. In accordance with the general findings of tennis coaches, junior female players in the age categories of 12&under and 14&under play less aggressively, but therefore more consistent, with few unforced errors, in their base line game. This is also consistent with a significantly lower percentage of achieved winners with the topspin backhand, which again points to a defensive game style.

An offensive game style, which is prevalent in modern tennis, is defined by a combination of tactical intentions: playing balls early after the bounce and closer to the net, playing sharp cross court and opening the court, sudden direction change, use of the dominant stroke, playing higher, strongly-rotated and deep balls, changing the pace, hiding the tactical intention and optimal covering of the court. Ultimately, as Smekal et al., (2001) detect, a player's game style is, to a great extent, also influenced by the opponent's game style, gender, court surface and weather conditions. Obviously, in base line games, professional tennis players use some of the above-listed tactical intentions. Their professional game is much more offensive, which is evident through the lower number of successful strokes, both with the forehand as well as the backhand topspins. Interestingly, professional and female tennis players use the forehand slice more efficiently, especially in defensive situations. Even more evident is the fact that professional tennis players often use their backhand slice as a stroke, with which they change the rhythm of the game, and thereby challenge their opponent's timing.

Finally, the proper ratio between a player's unforced errors, on the one hand, their opponent's forced errors—and that player's winners on the other hand, defines the player's offensive or defensive game style, which is identified as *aggressive margin* (Bernardini, De Vito, Falvo, Marino, & Montellanco, 1998; Smekal, et al., 2001).

This study did not address the spatial analysis of the execution of strokes (via a player's position and stroke ball bounce), stroke speed and game analysis from the perspective of results and specific mental conditions (breaks or game points etc.).

CONCLUSIONS

Match notation and statistics are used by a growing number of tennis coaches in order to analyse the efficiency of their players. By using different technologies, which are becoming more and more widely available, coaches are able to access data to better interpret unseen game patterns and dynamics of players, which in turn, better informs their coaching practice. This permits them to adapt their coaching to target the specific individual needs of each player as they plan and implement their training process.

ACKNOWLEDGEMENT

This study was supported by a grant from the programme group »Kinesiology of monostructural, polystructural and conventional sports« Faculty of sport, University of Ljubljana.

REFERENCES

Bernardini, M., De Vito, G., Falvo, M. E., Marino, S., & Montellanco, F. (1998). Cardiorespiratory adjustment in middle-level tennis players: Are long-term cardiovascular adjustments possible? In A. Lees, I. Maynard, M. Hughes, & T. Reilly. *Science and racket sports II* (pp. 20-26). London: E & FN Spon.

Brody, H. (2006). Unforced errors and error reduction in tennis. *Br J Sports Med, 40,* 397-400.

Brown, E., & O'Donoghue, P. O. (2008). Gender and Surface Effect on Elite Tennis Strategy. *ITF Coaching and Sport Science Review, 15*(46), 9-11.

Carvalho, J., Araújo, D., Travassos, B., Esteves, P., Pessanha, L., Pereira, F., et al. (2013). Dynamics of players' relative positioning during baseline rallies in tennis. *J Sports Sci., 31*(14), 1596-1605.

Cross, R., & Pollard, G. (2011). Grand Slam men's singles tennis 1995-2009 Part 2: Points, games and sets. *ITF Coaching and Sport Science Review, 53*(19), 3-6.

Djurovic, N., Lozovina, V., & Pavicic, L. (2009). Evaluation of Tennis Match Data - New Acquisition Model. *Journal of Human Kinetics, 21,* 15-21.

Downey, J. (1992). The use of notational analysis in determining optimal strategies in sport. In M. Hughes, *Notational Analysis of Sport I and II* (pp. 3-18). Cardiff: UWIC.

Elliott, B., Reid, M., & Crespo, M. (2003). *Biomechanics of advanced tennis.* London: ITF.

Fernandez-Fernandez, J., Sanz-Rivas, D., Fernandez-Garcia, B., & Mendez-Villanueva, A. (2008). Match activity and physiological load during a clay-court tennis tournament in elite female players. *Journal of Sports Sciences, 26*(14), 1589-1595.

Filipcic, T., Filipcic, A., & Pers, J. (2009). Comparative analysis of time, playing and movement factors between two different quality groups of wheelchair tennis player. In M. Kondric, & A. Filipcic. *Scientific approach in table tennis and tennis in Slovenia* (pp. 195-199). Toronto: Sport books publisher.

Filipcic, A., Pers, J., & Klevisar, A. (2006). *Comparison between young male and female tennis players in terms of time and movement characteristics.* Paper presented at the 4th World Congress of Science and Racket Sports, Madrid, Spain. - to referenco bi dala ven!!

Furlong, J. D. G. (1995). The service in lawn tennis: how important is it? In T. Reilly, M. Hughes, & A. Lees. *Science and Racket Sports* (pp. 266-271). London: E & FN Spon.

Gillet, E., Leroy, D., Thouvarecq, R., & Stein, J. F. (2009). A notational analysis of elite tennis serve and serve-return strategies on slow surface. *Journal of Strength and Conditioning Research, 23*(2), 532-539.

Hernández-Davo, H., Urbán, T., Sarabia, J. M., Juan-Recio, C., & Moreno, F. J. (2014). Variable training: effects on velocity and accuracy in the tennis serve. *J Sports Sci., 32*(14), 1383-1388.

Hizan, H., Whipp, P. R., & Reid, M. (2010). Validation of Match Notation (A Coding System) in Tennis. *Journal of Quantitative Analysis in Sports, 6*(3). Retrieved from http://www.bepress.com/jqas/vol6/iss3/11. doi:10.2202/1559-0410.1223

Hughes, M. D., & Bartlett, R. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences, 20,* 739-754.

Hughes, M. D., & Clarke, S. (1995). *Surface effect on elite tennis strategy.* In T. Reilly, M. Hughes, & A. Lees. *Science and Racket Sports* (pp. 272-277). London: E & FN Spon.

Hughes, M. D., & Franks, I. M. (2004). Notational Analysis of Sport: systems for better coaching. In P. O. O' Donoghue. *An Introduction to Performance Analysis of Sport.* London: Routledge.

Hughes, M. D., Hughes, M. T., & Behan, H. (2007). The evolution of computerised notational analysis through the example of racket sports. *International Journal of Sports Science and Engineering, 1*(1), 3-28.

Hurnik, E., Unierzyski, P., & O'Donohue, P. O. (2008). Reliability of a computerised system for recording location on a tennis court. *International Journal of Performance Analysis in Sport, 8*(3), 138-144.

Johnson, C. D., & McHugh, M. P. (2006). Performance demands of professional male tennis players. *Br J Sports Med., 40*(8), 696-699.

Johnson, C. D., McHugh, M. P., Wood, T., & Kibler, B. (2006). Performance demands of professional male tennis players. *British Journal Of Sports Medicine, 40*(8), 696-699.

Katic, R., Milat, S., Zagorac, N., & Djurovic, N. (2011). Impact of Game Elements on Tennis Match Outcome in Wimbledon and Roland Garros 2009. *Coll. Antropol., 35*(2), 341-346.

Martínez-Gallego, R. F., Guzmán, J., James, N., Pers, J., Ramón-Llin, J., & Vuckovic, G. (2013). Movement Characteristics of Elite Tennis Players on Hard Courts with Respect to the Direction of Ground Strokes. *Journal of Sports Science & Medicine, 12*(2), 275-281.

Morante, S., & Brotherhood, J. (2005). Match characteristics of professional singles tennis. *Med Sci Tennis, 10*(3), 12-13.

O'Donoghue, P. G. (2006). Variability in men's tennis singles tennis strategy at the US Open. In A. Lees, D. Cabello, & G. Torres. *Science and Racket Sports IV* (pp. 232-238). Oxon: Routledge.

O'Donoghue, P. O., & Ballantyne, A. (2004). *The impact of speed of service in Grand Slam singles tennis.* Paper presented at the Science and Racket Sports III, London and New York.

O'Donoghue, P. O., & Ingram, B. (2001). A notational analysis of elite tennis strategy. *Journal of Sports Sciences, 19*(2), 107-115.

O'Donoghue, P. O., & Ingram, B. (2000). Notational analysis of the cause of elite tennis players approaching the net in men's and ladies' singles at grand slam tournaments. In M. Hughes & F. Tavares. *Notational Analysis of Sports IV* (pp. 249-256). Porto: FCDEF.

Pers, J., Bon, M., Kovacic, S., Sibila, M., & Dezman, B. (2002). Observation and analysis of large-scale human motion. *Human Movement Science, 21*(2), 295-311.

Petkovic, M., Jonker, W., & Zivkovic, Z. (2001). *Recognizing Strokes in Tennis Videos using Hidden Markov Models.* In: IASTED International Conference on Visualization, Imaging and Image Processing, VIIP 2001 (pp. pp. 512-516). Marbella: IASTED/Acta Press.

Reid, M., McMurtrie, D., & Crespo, M. (2010). The relationship between match statistics and top 100 ranking in professional men's tennis. *International Journal of Performance Analysis of Sport, 10,* 131-138.

Smekal, G., Von Duvillard, S., Rihacek, C., Pokan, R., Hofmann, P., Baron, R., Tschan, H., & Bachi, N. (2001). A physiological profile of tennis match play. *Medicine and Science in Sports and Exercise, 33 (6),* 999-1005.

Terroba, A., Kosters, W., Varona, J., & Manresa-Yee, C. S. (2013). Finding optimal strategies in tennis from video sequences. *Int. J. Patt. Recogn. Artif. Intell., 27*(6). DOI: 10.1142/S0218001413550100

Torres-Luque, G., Cabello-Manrique, D., Hernández-García, R., & Garatachea, N. (2011). An analysis of competition in young tennis players. *European Journal of Sport Science, 11*(1), 39-43.

Unierzyski, P., & Wieczorek, A. (2004). *Comparison of tactical solutions and game patterns in the finals of two grand slam tournaments in tennis.* In A. Lees, J.-F. Kahn, & I. W. Maynard. *Science and racket sports III* (pp. 169-174). Oxon: Routledge.

Vergauwen, L., Madou, B., & Behets, D. (2004). Authentic evaluation of forehand groundstrokes in young low- to intermediate-level tennis players. *Med Sci Sports Exerc, 12,* 2099-2106.

Vergauwen, L., Spaepen, A. J., Lefevre, J., & Hespel, P. (1998). Evaluation of stroke performance in tennis. *Medicine and Science in Sports and Exercise, 30,* 1281-1288.

Verlinden, M., Van Ruyskensvelde, J., Van Gorp, B., De Decker, S., Goossens, R., & Clarijs, J.-P. (2004). *Effect of gender and tennis court surface properties upon strategy in elite singles.* A. Lees, J.-F. Kahn, & I. W. Maynard. *Science and racket sports III* (pp. 163-168). Oxon: Routledge.

Vuckovic, G., Pers, J., James, N., & Hughes, M. (2010). Measurement error associated with the SAGIT/Squash computer tracking software. *European Journal of Sport Science, 10*(2), 129-140.

Williams, A. M., Ward, P., Smeeton, N. J., & Allen, D. (2004). Developing Anticipation Skills in Tennis Using On-Court Instruction: Perception versus Perception and Action. *Journal of Applied Sport Psychology, 16*(4), 350-360.

Williams, A. M., Ford, P. R., Eccles, D. W., & Ward, P. (2011). Perceptual-cognitive expertise in sport and its acquisition: Implications for applied cognitive psychology. *Applied Cognitive Psychology, 25*(3), 432-442.