Tjaša Filipčič*[1]
Aleš Filipčič[2]

ANALYSIS OF MOVEMENT VELOCITY AND DISTANCE COVERED IN WHEELCHAIR TENNIS

ANALIZA HITROSTI GIBANJA IN PREVOŽENE RAZDALJE V TENISU NA VOZIČKU

ABSTRACT

New technologies enable new approaches to sports science, including sports adapted for people with physical handicaps. The research reported in this paper is focused on a comparative analysis of workload (movement velocity and distance covered) between winners and losers in wheelchair tennis. It also focuses on two different quality groups of players (recreational and top-level). Fifteen tennis players with physical impairment covered an average distance of 613 m in a match, 4.1 m in a game and 6.11 m in each rally. Statistically significant differences between the two groups of players have been found in all three distance segments: total match distance covered, game distance covered and rally distance covered. The average velocity in the rally was 0.93 m/s. Statistically significant differences were found in the average movement velocity for top-level players. Those players also achieved higher values in the maximum movement velocity in the rally; however, the difference was not statistically significant. No significant differences in the average velocity and in the maximum velocity were found between the winners and the losers.

Keywords: wheelchair tennis, workload, velocity, distance covered

POVZETEK

Nove tehnologije omogočajo nove pristope v raziskovanju v športu kar velja tudi za šport invalidov. Raziskava ponuja primerjavo obremenitve (hitrost in prevožena razdalja) med zmagovalci in poraženci ter vrhunskimi in rekreativnimi igralci. 15 teniških igralcev z gibalno oviro je v povprečju prevozilo 613 m na tekmo, 46,1 m v igri in 6,11 m v točki. Našli smo statistično značilne razlike v prevoženi razdalji med zmagovalci/poraženci in vrhunskimi/rekreativnimi igralci. Povprečna hitrost je znašala 0,93 m/s. V povprečni hitrosti smo statistično značilne razlike našli med vrhunskimi in rekreativnimi igralci. Vrhunski teniški igralci so dosegli tudi višjo makimalno hitrost, vendar razlika ni bila statistično značilna. Med zmagovalci in poraženci nismo našli statistično značilnih razlik v povprečni in maksimalni hitrosti.

Ključne besede: tenis na vozičku, obremenitev, hitrost, prevožena razdalja

[1] ***Faculty of Education, University of Ljubljana, Slovenia***

[2] ***Faculty of Sport, University of Ljubljana, Slovenia***

Corresponding author:
Faculty of Education, University of Ljubljana
Kardeljeva pl.16, 1000 Ljubljana, Slovenia
Tel.: +386 31 704 876
E-mail: tjasa.filipcic@guest.arnes.si

INTRODUCTION

Match analysis is an area of sports science that has matured over recent decades and has taken advantage of technological advances. It is also a term used to describe the analysis of actual sports competition. Two different approaches can be observed: firstly, practical match analysis exercises that are used within media and coaching contexts to evaluate individual matches. This type of match analysis activity is characterized by the need to produce rapid performance information. Secondly, theoretical match analysis is a research discipline within sport that can discover general properties of competitive sport, rather than merely retrospectively analysing unique characteristics of matches for historical purposes. Theoretical match analysis research is important for all five purposes of notational analysis: technical and tactical evaluation, analysis of movement, performance modelling and effectiveness of coach and player education (O'Donoghue, 2004).

Several studies of match analysis in different able-bodied sports (including racket sports) have been published: squash, badminton, table tennis and tennis (Lees, Kahn and Maynard, 2004). That is not so for adapted sport[1] and in particular for wheelchair tennis. Most of the tennis principles that apply to the able-bodied game apply to wheelchair tennis, especially in areas such as strokes, grips, tactics, corrective techniques, teaching methodologies, progression, mental training and match preparation. Wheelchair tennis can be defined as tennis played in a seated position (Polic, 2000). Nevertheless, differences need to be pointed out, such as: methods of mobility, movements to the ball and two bounces allowed, basic stroke sequence, recovery approaches, generating torque, recovery and physical consideration.

In spite of the similarities, little research of wheelchair tennis has been done thus far. Bullock and Pluim (2003) analysed the duration of rally on a synthetic surface. In three matches (449 rallies) the average rally lasted 9.6 seconds. No results about the distance covered and the movement velocity on a wheelchair were reported. The authors suggested that more in-depth analysis was needed and a greater number of rallies should be analysed.

Extended research into wheelchair tennis was done by Filipčič (2008), who analysed its time characteristics. Data were obtained at 22 tennis singles matches and analysed with computer-vision-based software application called the SAGIT/TENNIS tracking system, which had been developed at the Faculty of Electrical Engineering in Ljubljana. This software application was used to automatically obtain player motion data from the digitised video recordings of a tennis match. Within the time characteristics, it was established that the active part represented 19.68% of the total playing time, while the passive one represented 80.32%. The average time of an individual rally lasted 4.16 seconds and 2.23 strokes were played in each rally. In the first time class, 70% of all rallies were completed. Each half of the tennis court was divided into 14 fields in order to measure the average time spent in each field. It was determined that most of the active time was spent in Fields 1 and 4, representing the base positions in wheelchair tennis. There were no statistically significant differences between the winners and losers in the percentage of time spent in a particular field.

Perez Tejero, Navarro and Sampedro (2005) carried out research in wheelchair basketball. They analysed the distance covered and the velocity of 10 players on wheelchairs at 13 basketball matches. The deficiency of this research is that only the first 10 minutes of the game of each match

[1]i.e sport adapted to the abilities of physically handicapped athletes.

were analysed, which represents only a quarter of the game played. The average distance covered of all players in an individual active phase was 44.85 m (SD=3.5 m). Regarding the movement velocity in a wheelchair they found out that the average velocity was 1.6 m/s (SD=1.1 m/s). The maximum velocity was 6.3 m/s (22.6 km/h) and the highest average velocity of 10 players was 5.5 m/s (19 km/h), (SD=0.8 m/s).

New technologies enable new approaches to sports science. These include a computer-vision-based software application that was used to automatically obtain player motion data from the digitised video recordings of a tennis match (Perš and Kovačič, 2001).

It is therefore possible to analyse the workload (distance covered and movement velocity) of wheelchair tennis players in a singles match with sophisticated technology. Filipčič, Perš and Klevišar (2006) used the SAGIT/TENNIS tracking system; 12 male and 12 female tennis players (age: 14 years) were involved in the research. The researchers measured and compared the distance covered between both sexes as well as between the winners and losers in the entire match (active and passive part of the game). It was determined that male players, on average, covered more (3.297 m) than female ones (2.713 m), but the differences were not statistically significant. The winners covered less (2.950 m) than the losers (3.060 m), but here too no statistically significant differences were found.

Vučković, Dezman, Erculj, Kovačič and Perš (2004) examined the distance covered in a set, in an active part and in an individual active phase among different teams of squash players. They observed statistically significant differences among top-level foreign players, Slovenian top-level players and Slovenian recreational players in three segments of the game. The greatest distance in an active part was covered by top-level foreign players (795.18 m). Almost half that distance was covered by Slovenian top-level players. The shortest distance was covered by Slovenian recreational players.

Pori and Sibila (2006) analysed the distance covered and velocity during a handball match; 36 male handball players of different playing positions were involved. Players covered 620 m of movements with an average velocity above 5.2 m/s and a maximum velocity of 7.7 m/s.

No similar research projects were found in wheelchair tennis; especially any that focused on workload. It is this limitation that justifies the present research to define the workload in wheelchair tennis: the distance covered and the movement velocity in particular.

METHODS

Participants

The sample of participants comprised 15 male wheelchair tennis players. The mean age was 39.06 (SD=8.24). Fourteen players had a complete and acquired spinal cord injury (Th 6 - Th 12), while one player had a congenital physical impairment. They were wheelchair users and had been playing wheelchair tennis for at least five years. All of the participants were right-handed. Five players were on the world wheelchair tennis ranking list, while 10 were on the Slovenian ranking list (best 10). None of the players played tennis at the competition level before the injury. All players were training regularly (with at least two training sessions per week).

Instruments and procedure

The relevant data were obtained at the Triglav Kranj Tennis Centre (Slovenia) where all the matches were played on a hard court under the same conditions for all the participating players. All tennis matches were recorded with fixed SVHS video cameras (Ultrak CCD Color KC 7501 CP) recording at 25 frames per second. 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 cameras did not interfere with the play and could not be hit by the tennis ball. The video recordings were digitised using the Video DC30* - video digitiser hardware (Miro, Germany) with a resolution of 384x576 at 2 MB.s^{-1} data rate, while the processing was carried out at a resolution of 384 x 288 pixels. Digital images were processed with the SAGIT/TENNIS tracking system.

Conversion into numerical data was carried out by the following steps:

1. recording tennis matches on S-VHS video cassettes and DVDs
2. re-recording and compression of the recordings into DVD format
3. calibration of the recordings (time and space calibration)
4. data processing with the SAGIT/TENNIS tracking system (distance covered and movement velocity)
5. importing data into the database
6. exporting data from the database; data processing with statistical programme SPSS 13.0 for Windows

The research reported in this paper was undertaken in compliance with the Helsinki Declaration.

Sample of variables

The sample of variables was obtained at 22 singles matches (3.307 rallies). The rally indicates the time when the ball is in play; i.e. from the moment it is thrown from the hand when serving until it hits the net (error) or it touches the ground after the 3rd bounce (winning stroke).

The sample of variables was dived into three groups:

1. distance covered (DC): the average distance covered in a match, in a game and in a rally;
2. average velocity (AV) in a rally;
3. maximum velocity (MV) in a rally.

All variables were compared between two groups of players (top-level/recreational and winners /losers).

Data analysis

The basic statistical parameters of all time variables were computed in the first phase of the data analysis (min, max, sum, mean, K-S). In the second part, ANOVA was used to compare statistical differences between two levels of players and winners/losers in the distance covered and in the movement velocity.

The research reported in the paper was undertaken in compliance with Helsinki Declaration.

RESULTS

Distance covered in wheelchair tennis

On average, all of the players covered the distance of 613 m in a match, 46.1 m in a game and 6.11 m in each rally, as presented in Table 1.

Statistically significant differences between the two groups of players (top-level/recreational) were found in all three segments of the distance covered: DM, DG and DR (Table 2). The same was found when winners and losers were compared (Table 3).

Table 1: Descriptive statistics for distance covered for all players

Variable	N	MIN	MAX	SUM	MEAN	SD	K-S	SIG
DM	22	186.43	1667.06	26973.25	613.02	273.24	1.24	0.09
DG	22	9.05	123.71	2031.04	46.16	26.933	1.16	0.13
DR	22	3.39	12.23	268.99	6.11	2.023	1.00	0.26

Legend: DM – distance in a match; DG – distance in a game; DR – distance in a rally

Table 2: ANOVA for distance covered between top-level and recreational players

VARIABLE	GROUP	MEAN	SD	F	P
DM	A	712.21	334.47	6.546	0.014
	B	513.83	142.80		
DG	A	54.20	31.53	4.217	0.046
	B	38.11	18.84		
DR	A	6.93	2.44	8.628	0.005
	B	5.28	.98		

Legend: DM – distance in a match; DG – distance in a game; DR – distance in a rally; A – top-level players; B – recreational players

Table 3: ANOVA for distance covered between winners and losers

VARIABLE	GROUP	MEAN	SD	F	P
DM	W	643.21	274.44	2.791	0.011
	L	582.84	275.05		
DG	W	65.94	24.47	10.048	0.000
	L	26.37	8.15		
DR	W	6.47	2.28	3.204	0.004
	L	5.75	1.70		

Legend: DM – distance in a match; DG – distance in a game; DR – distance in a rally; W – winners; L – losers

Average and maximum velocity in wheelchair tennis

The average velocity in the rally was 0.93 m/s (Table 4), while the average maximum velocity was 3.29 m/s. The highest velocity measured in an individual player was an even 5 m/s.

Statistically significant differences between the top-level and the recreational players were found for the average velocity (P=0.000). The top-level players also achieved higher values in variable MV; however, the difference was not statistically significant (P=0.449) as seen in Table 5. No

significant differences in the average velocity (P=0.099) and in the maximum velocity (P=0.813) were found between the winners and the losers (Table 6).

Table 4: Descriptive statistics for average and maximum velocity for all players

VARIABLE	*N*	*MIN*	*MAX*	*MEAN*	*SD*	*K-S*	*SIG*
AV	22	0.54	1.40	0.93	0.21	0.69	0.72
MV	22	2.46	5.00	3.29	0.56	0.92	0.36

Legend: AV – average velocity in a rally; MV- maximum velocity in a rally

Table 5: ANOVA for average and maximum velocity between top-level and recreational players

VARIABLE	GROUP	MEAN	SD	F	P
AV	A	1.08	0.17	47.473	0.000
	B	0.77	0.11		
MV	A	3.36	0.47	0.585	0.449
	B	3.23	0.64		

Legend: AV – average velocity in a rally; MV – maximum velocity in a rally; A – top-level players; B – recreational players

Table 6: ANOVA for average and maximum velocity between winners and losers

VARIABLE	GROUP	MEAN	SO	F	P
AV	W	0.98	0.23	2.845	0.099
	L	0.87	0.17		
MV	W	3.27	0.47	0.056	0.813
	L	3.31	0.65		

Legend: AV – average velocity in a rally; MV – maximum velocity in a rally; W – winners; L – losers

DISCUSSION

Wheelchair mobility is an important factor of success in wheelchair tennis, as proposed by Polic (2000), Bullock & Pluim (2003) and Bullock (2006). In wheelchair tennis, the distance covered is very important. Specifically, movement enables the player to adequately prepare himself/herself for a stroke and to execute the maximum number of strokes. The players have to start moving towards the approaching ball with a certain initial velocity. This means that players move to the middle part of the court right after the execution of the previous stroke, which is made with an inward or outward turn. When comparing the top-level and the recreational players as well as the winners and the losers, we established that a greater extent of movement means greater playing efficiency.

Vučković, Dezman, Erculj, Kovačič and Perš (2004) came to similar conclusions. The movement velocity is also an important factor of success in many open sports games, particularly in wheelchair tennis. In this research, the average movement velocity was 0.93 m/s. This value is lower than the one in the research done by Perez Tejero, Navarro and Sampedro (2005), who examined wheelchair basketball. There, the average movement velocity was 1.6 (± 1.1) m/s.

There are three reasons for lower velocity. Firstly, in wheelchair tennis the player moves on a smaller part of the court, mostly near the base line. Secondly, it is more difficult to push the wheelchair with a racket in hand. Thirdly, the movement consists of moving towards the

approaching ball, stopping and execution of stroke, as well as returning to the optimal position for executing the next stroke. Holding the racket diminishes velocity.

This was confirmed by Goosey, Tolfrey and Moss's research (2005), where the velocity of eight wheelchair tennis players in a 20 m sprint was compared. In the first case, the tennis players were holding a racket and in the second one they were not. When the players were pushing the wheelchair without a racket, they achieved the maximum velocity of 4.39 m/s (SO=0.74 m/s); with a racket, the velocity diminished to 4.22 m/s (SO=0.06 m/s). The greatest differences were observed in the first three pushes. All of these facts prove that differences between pushing the wheelchair with or without a racket do exist. These differences influence the velocity achieved on the tennis court.

When comparing the average and the maximum velocity between the top-level and the recreational players, as well as between the winners and the losers, we established that the players on the global ranking list were faster, but they did not achieve higher maximum velocity. These results are in accordance with the findings of Vučković (2005). He established that the best squash players in the world were the fastest. Their average velocity was 1.48 m/s in the active part of a set. The average velocity of the top-level wheelchair tennis players was 1.29 m/s and the one of the recreational players was 1.27 m/s.

CONCLUSION

It was determined that the distance covered and movement velocity are important workload factors in wheelchair tennis. They differentiate the top-level players from the recreational ones and the winners from the losers.

Due to the nature of the game of tennis, where many errors occur, the rallies and the distance covered are short. We anticipate that with the development of the game, the rallies and the distance covered will be prolonged. This will lead to greater differences among various quality levels of players and between the winners and the losers.

The movement velocity in wheelchair tennis is lower than in other wheelchair sports. In this research, it has been established that the movement velocity differentiates better players from worse ones, and the winners from the losers, less than the distance covered does.

This article presents the first attempt to examine the workload in wheelchair tennis. Therefore, further research is needed in this regard, particularly regarding workload on different surfaces, in female players, in players with different playing styles, with different impairments and other factors.

REFERENCES

Bullock, M., & Pluim, B. (2003). Wheelchair Tennis and Physical Conditioning. *ITF Wheelchair Tennis Coaches Review* 3 (9), 2–10.

Bullock, M. (2006). *Physical Conditioning for Wheelchair Tennis*. Interactive E-learning Presentation / on line/. Retrieved February 2, 2009 from: http://www.itfcoaching.com/Physical-Conditioning-for-Wheelchair-Tennis/player.html.

Filipčič, T. (2008). *Igralne značilnosti gibalno oviranih v tenisu na vozičku in njihov vpliv na uspešnost igranja [Playing Characteristics of Physically Impaired and Their Influence on Success in Wheelchair Tennis].* Unpublished doctoral dissertation, Ljubljana: Univerza v Ljubljani, Fakulteta za šport.

Filipčič, A., Perš, J., & Klevišar, A. (2006). Comparison between Young Male and Female Tennis Players in Terms of Time and Movement Characteristics. *Poster presented at the 4th World Congress of Science and Racket Sports, Madrid, 2006.*

Goosey Tolfrey, V.L., & Moss, A.D. (2005). Wheelchair Velocity of Tennis Players during Propulsion with and without the Use of Racquets. *Adapted Physical Activity Quarterly* 22 (3), 291–301.

Lees, A., Kahn, J.F. & Maynard, I. (2004). *Science and Racket Sports III*. London: Routledge.

O'Donoghue, P. (2004). Match analysis in racket sports. In A. Lees, J.F. Kahn, & I. Maynard (Eds.), *The Proceedings of the Eight International Table Tennis Federation Sports Science Congress and the Third World Congress of Science and Racket Sports, Paris, 2003, "Science and Racket Sports III"* (pp. 155–163). London: Routledge.

Perez Tejero, J., Navarro, E. & Sampedro, J. (2005). Distance Covered and Velocity during Wheelchair Basketball Related Players Functional Classification. *The Proceedings of the 15th International Symposium Adapted Physical Activity, Verona, 2005* (pp. 18–19), Verona: Tipolitografija don Calabria.

Perš, J. & Kovačič, S. (2001). Tracking People in Sport: Making Use of Partially Controlled Environment. In W. Skarbek (Ed.), *The Proceedings of the 9th International Conference CAIP 2001, Warsaw, 2001, "Computer Analysis of Images and Patterns"* (pp. 374–382), Berlin: Springer.

Polic, M. (2000). *ITF Wheelchair Tennis Coaches Manual*. London: ITF.

Pori, P., Sibila, M. (2006). Analysis of High-intensity Large Scale Movements in Team Handball. *Kinesiologia Slovenica* 12 (2), 51–58.

Vučković, G. (2005). *Tehnično-taktične značilnosti igranja različno kakovostnih skupin igralcev squasha* [Technical and tactical playing characteristics of differently ranked groups of squash players]. Unpublished doctoral dissertation. Ljubljana: Fakulteta za šport.

Vučković, G., Dežman, B., Erčulj, F., Kovačič, S., & Perš, J. (2004). Differences between the Winning and the Losing Players in a Squash Game in Terms of Distance Covered. In A. Lees, J.F. Kahn, & I. Maynard (Eds.), *The Proceedings of the Eight International Table Tennis Federation Sports Science Congress and the Third World Congress of Science and Racket Sports, Paris, 2003, "Science and Racket Sports III"* (pp. 202–226), London: Routledge.