©Journal of Sports Science and Medicine (2013) **12,** 66-73
http://www.jssm.org

Research article

The Effect of Court Location and Available Time on the Tactical Shot Selection of Elite Squash Players

Goran Vučković [1]✉, Nic James [2], Mike Hughes [2], Stafford Murray [3], Goran Sporiš [4] and Janez Perš [5]
[1] Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia; [2] London Sport Institute, Middlesex University, London, England; [3] English Institute of Sport, Manchester, England; [4] Faculty of Kinesiology, University of Zagreb, Zagreb, Croatia; [5] Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia

Abstract
No previous research in squash has considered the time between shots or the proximity of the ball to a wall, which are two important variables that influence shot outcomes. The aim of this paper was to analyse shot types to determine the extent to which they are played in different court areas and a more detailed analysis to determine whether the time available had an influence on the shot selected. Ten elite matches, contested by fifteen of the world's top right handed squash players (age 27 ± 3.2, height 1.81 ± 0.06 m, weight 76.3 ± 3.7 kg), at the men's World Team Championships were processed using the SAGIT/Squash tracking system with shot information manually added to the system. Results suggested that shot responses were dependent upon court location and the time between shots. When these factors were considered repeatable performance existed to the extent that one of two shots was typically played when there was limited time to play the shot (< 1.20s). For example, it was clear that when players did not have a lot of time to hit the ball (low time i.e. < 1.06s, and mid time i.e. 1.06 - 1.20s) in the front left corner close to the side wall, the crosscourt lob was used frequently (44.30% and 36.31% respectively) whereas when there was more time this shot was seldom used (13.64%). Consequently variant and invariant behaviour were shown to exist in elite squash although for the first time it was suggested that the availability of time to play a shot contributed to which of these behaviours was evident. This analysis could be extended by adopting a case study approach to see how individual differences in strategy and tactics affect shot selections.

Key words: Strategy, tactics, SAGIT, invariant behaviour.

Introduction

At present there is no known analysis in squash, or indeed in any of the racket sports, that has quantified the time available to respond to different shot types. An understanding of the time interval between shots and the movement characteristics of the player responding to different shots according to the court positions might facilitate a better understanding of the dynamics that determine shot selection. One method for measuring these variables is the SAGIT/Squash tracking system (Perš et al., 2002) which has been used by Vučković and colleagues (e.g. 2003; 2005; 2008; 2010).

McGarry and Franks (1994; 1995) analysed championship squash (1987 and 1988) and were unable to establish an individual pattern of play (which they referred to as "invariant behaviour") for matches played against different opponents. However, consistent shot responses to some types of shot were found when competing against the same opponent. This suggests that players are able to adapt their shot responses according to their opponent's strengths and weaknesses, referred to as tactics i.e. punctual adaptations to in-match variables such as an opponent's strengths and weaknesses, by Gréhaigne and Godbout (1995). McGarry and Franks (1996) pointed out that the preceding shot condition alone might be too simplistic a predictor of shot response, rather than a combination of factors, such as the pace of the shot, proximity of the ball to a wall and the court location of the player and opponent, and so on.

Murray and Hughes (2001) split the squash court floor into 16 areas and recorded the incidence of shot types played from each of these areas by a single player over 5 matches against different opponents. This analysis did not account for the time available to play the shot, but did give an indication of the proportionate shot types for each location (as undertaken by Hong et al., 1996). Both of these research papers implicitly suggested that this type of analysis could indicate a typical playing profile for a player.

Previous research has therefore suggested that a playing strategy, elements decided in advance of the match such as playing with a fast tempo (Gréhaigne and Godbout, 1995), may be evident for elite players although court location and preceding shot type alone are unlikely to be sufficient predictors. This research will thus expand upon the work of Murray and Hughes (2001) and provide further information on shot types with respect to the previous shot. A refinement in the size and shape of the areas used for shot locations will also be used in response to McGarry and Franks (1996) suggestion about the preceding shot condition. This paper will also focus more on the best shots played i.e. those which require shot responses from close to the side walls as well as those areas where most shots are played from. By excluding shots played from areas away from the side walls it will be possible to suggest what the likely response will be if a player hits a particular shot accurately. Consequently, the aim of this paper was to analyse shot types to determine the extent to which they were played in different court areas, and a

Received: 01 June 2012 / Accepted: 22 November 2012 / Published (online): 01 March 2013

more detailed analysis to determine whether the time available or prior shot type had an influence on the shot selected.

Methods

Sample of matches and participants

Matches were recorded at the men's World Team Championship (n = 10) played in 2003. The sample consisted of fifteen of the world's top squash players (age 27 ± 3.2, height 181.0 ± 0.06 m, weight 76.3 ± 3.7 kg). Only matches where both players were right handed were included, because a left handed player against a right handed player skews the patterns of play, similarly for two left handed players. Ethical approval for the study was granted by a university ethics committee and informed written consent was obtained from all participants.

Procedure

All matches took place on a court set up with a PAL video camera (JBL UTC – A6000H, Korea) attached to the ceiling above the central part of the court. The camera placement and methodology for transferring the video images into SAGIT/Squash has been documented in Vučković et al. (2009). The SAGIT/Squash system enables input of additional information including the location of the ball at contact. A separate input system was designed to allow the operator to view the video taken from the overhead camera and the ball could be marked on the court via a touch sensitive interface. A secondary input related to the ball height above the floor was then processed. This estimation of this input was facilitated by viewing a second video source taken from behind the court, about 15m behind, and 3m above the surface of the court. The software then calculates the x and y coordinates of the ball location. For the purposes of this study these x y coordinates were categorised as 1 of 15 areas (Figure 1). The logic used to determine the size and shape of each area was to distinguish between shots that were played close to the side walls (areas 1 to 6), shots that were played from similar positions but not close to the side walls (areas 7 to 12) and from the middle of the court (areas 13 to 15). The area shapes at the front and back of the court were selected to reflect the tendency of the ball to deviate towards the middle of the court when hitting the side wall.

Reliability

Reliability and accuracy procedures found that the average error, for balls that had been placed at known coordinates, was 9.15cm. Twelve games were viewed for a second time and the shot locations and shot types of 2907 shots recorded in an Excel spread sheet. These were compared with those calculated in SAGIT/Squash resulting in an overall agreement of 88.90% for the court location data and 99.52% for shot type. However since an overall value can hide potential weaknesses in the data capture process individual cells were subjected to further location specific analyses and the minimum agreement was 88%. This information enabled any future data analysis using the SAGIT/Squash system to be interpreted appropriately.

Statistical analysis

Chi square tests were used to assess differences in the frequencies of shots, with the significance level accepted at 5%, with Cramer's Phi used to signify effect sizes. Kruskal Wallis tests were used to ascertain differences in time between shots that were played in the front, middle and back areas of the court. Data collection, treatment and analysis were performed using Microsoft Office Access and Excel 2003 and the IBM SPSS statistical package (v 19.0).

Results

The analysis of shots was undertaken in two stages. First *shot selections* were examined for all areas of the court where over 3.5% of the total shots were played (Figure 2). Secondly the types of shot played from specific court locations were examined to determine whether the time

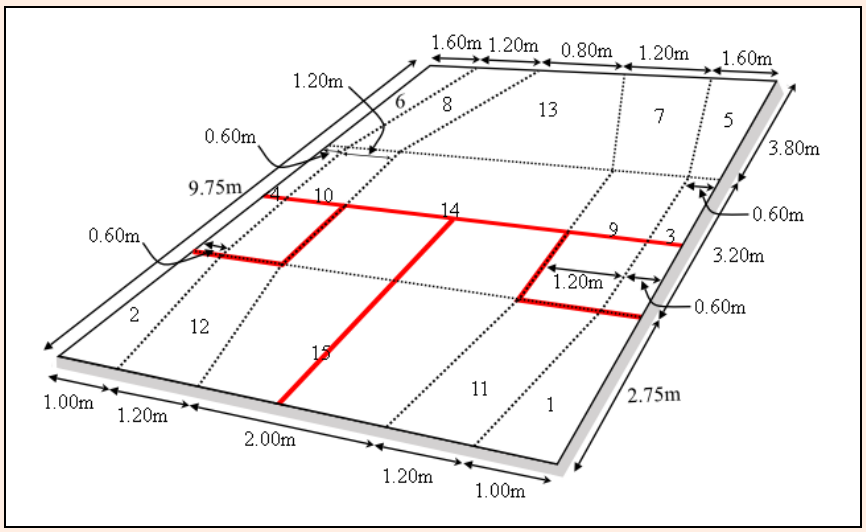

Figure 1. Dimensions of the court floor divided into 15 areas.

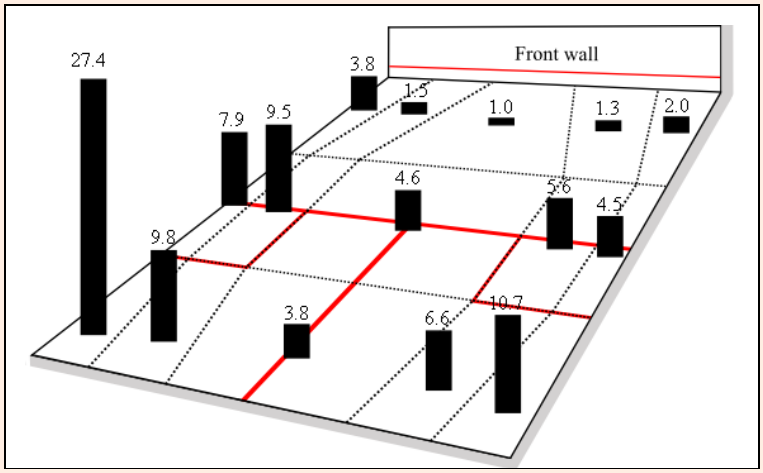

Figure 2. Percentage occurrence of shots played in each area of the court.

available had an influence on shot selection *(shot selection based on time available)*.

Shot selection

There was a high proportion of straight drives overall (41.76% of 10,062 shots), with this shot particularly predominant in the back corners of the court, more so in the left (backhand) side (70.4%, Figure 3). The crosscourt drive was used more in the back right corner (27.5% and 33.8%; areas 11 and 1 respectively) than the back left (10.1% and 11.6%; areas 12 and 2 respectively). In contrast the greatest variation in shot types was evident in the middle areas of the court. More shots were aimed towards the left side of the court and less than 10% of shots played from the front areas which made up 38.97% of the total floor area.

It was evident (Figure 3) that at the back of the court shots tended to be hit low and hard to return the ball to the back areas whereas when shots were played further forward the drop shot (towards the front) and the lob (to the back) became more prevalent corresponding to the proximity to the front wall.

Shot selection based on time available

The time between shots (N = 9587; winning shots were excluded because the next shot was a service) were sorted according to the areas from and to where the ball was hit. The average time from the first shot to the second tended to be shorter when the second shot was played from the middle of the court (chi square = 3076.54, df = 2, $p < .001$) than from the front or back of the court (Table 1). It was also evident that the time between shots was not simply determined by the distance the ball was travelling. For example a ball hit from the front to the back of the court (mean time = 1.60s) travelled less distance as a ball hit from the back to the back of the court (mean time = 1.57s).

In order to analyse the impact that the available time to hit the ball had on shot selection, the area with the greatest number of shots played in the back, middle and front areas of the court were selected. The time prior to all shots played in these three areas were examined and

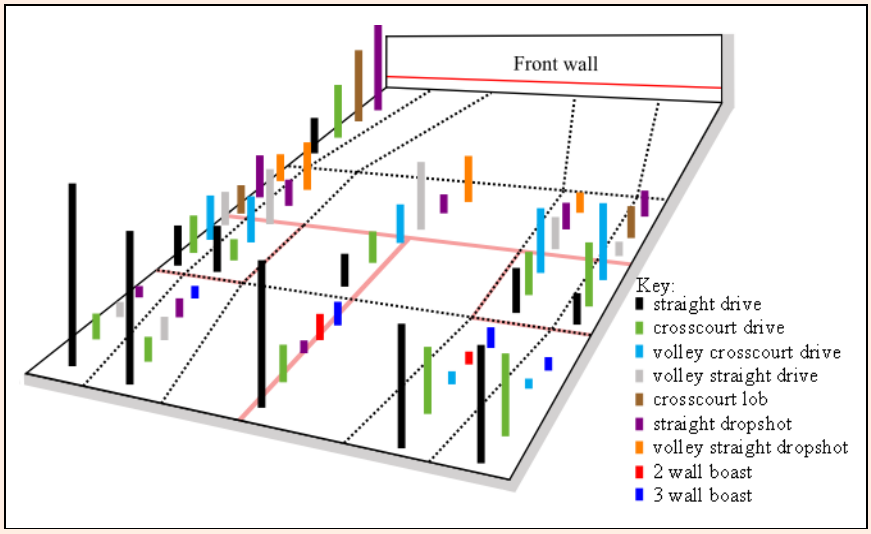

Figure 3. Percentage occurrence of shot types for each area.

Table 1. Descriptive statistics for time taken between shots hit from the front, middle and back of the court.

Area of court ball hit from	Area of court ball hit to	N	Mean time (s)	Standard deviation	Minimum	Maximum
Front	Front	376	1.11	.20	.40	2.24
	Middle	188	1.05	.34	.48	2.32
	Back	340	1.60	.46	.84	2.76
Middle	Front	525	1.15	.18	.60	2.52
	Middle	1009	1.07	.25	.52	2.72
	Back	1481	1.55	.37	.80	2.80
Back	Front	367	1.44	.34	.84	2.68
	Middle	1439	1.15	.27	.68	2.84
	Back	3862	1.57	.36	.84	2.76

categorised into three levels of time between shots (low, mid and long) to try to achieve relatively similar numbers of shots for each category. Boundaries were also chosen based on the distribution of times for each category which were different because of the lack of volleys in the front of the court and the types of shot prevalent in the different areas (Figure 3). This resulted in boundaries that were different for the different areas of the court (Table 2).

The principal shot played in area 2 was the straight drive irrespective of the time available (Figure 4) with straight drop shots predominately played when the time between shots was less than 1.60s (Table 2).

Over 97% of shots played in area 10 were played to the back left, back right and front left corners of the court (Figure 5). Shots tended to be volleys when the ball was hit relatively early (less than 1 second after the previous shot, Table 2) with more shots directed to the front of the court (40%) than when the ball was hit later (30%).

In area 6 the front right of the court was played to very occasionally using two wall boasts (2.31% of total shots) and crosscourt drop shots (2.05%) and so were not shown in the Figure 6. It was clear that when players did not have a lot of time to hit the ball (low and mid time) the crosscourt lob was used frequently (44.30% and 36.31% respectively) whereas when there was more time this shot was seldom used (13.64%). In contrast it was only in the long time category that the straight drive was used over 10% of the time (22.73%). The proportion of drop shots increased by about 10% when more time was available (mid and high time) compared to the low time category (21.52%).

Discussion

The high incidence of shots played from the back left of the court (37.2%), in comparison to the back right (17.3%), suggested a strategy was used (Gréhaigne and Godbout, 1995). This was evident in the higher incidence of crosscourt drives played from the forehand (right) side of the court seemingly to apply pressure on the backhand side, concurring with the findings of Hong et al. (1996) and Murray and Hughes (2001). From a strategy perspective this high percentage of shots returning the ball back to the back of the court is symptomatic of playing safely i.e. attempting to minimise the chance of error as opposed to maximising the chance of a winner. Accurate shots played to the back of the court also allows a player to position themself in the tactically astute T area at the time of the opponent's shot, shown to be a good indicator of playing standard by Vučković et al. (2009). Being in the T area at the time of the opponent's shot also allows a player the opportunity to return shots from the middle of the court, particularly by volleying the ball which reduces the time available for the opponent's next shot. Volleying in the middle of the court also resulted in a greater variety of shots in this area compared to the front and back of the court, which also increases the pressure on the opponent (Hughes and Robertson, 1998; McGarry and Franks, 1996). Players hit a higher incidence of crosscourt shots (ground strokes and volleys) to the back of the court from the right compared to the left middle areas. This again suggests the strategy of playing the ball to the back left of the court pressurising the opponent's backhand. In comparison, when playing from the middle left of the court, players were more likely to play attacking shots (straight drop shots, both ground strokes and volleys) to the front of the court. This suggests that players use different shots on the forehand and backhand sides although the reason is unclear. It may be that the speed of the ball is the key determinant for a player's decision. If forehands are hit harder and faster than backhands then straight drives on the right side of the court may be travelling too fast to be

Table 2. Descriptive statistics for time prior to shots played from selected areas in the front (6), middle (10) and back (2) of the court.

Area of court ball hit from	Area of court ball hit to	N	Mean time (s)	Standard deviation	Minimum	Maximum
Front (6)	Low (<1.06s)	79				
	Mid (1.06s to < 1.22s)	179	1.20	0.22	0.84	2.52
	Long (≥1.22s)	132				
Middle (10)	Low (<1.00s)	206				
	Mid (1.00s to <1.20s)	276	1.11	0.24	0.56	2.56
	Long (≥1.20s)	221				
Back (2)	Low (≤1.20s)	1005				
	Mid (1.21s to <1.60s)	975	1.48	0.40	0.76	2.76
	Long (≥1.60s)	1083				

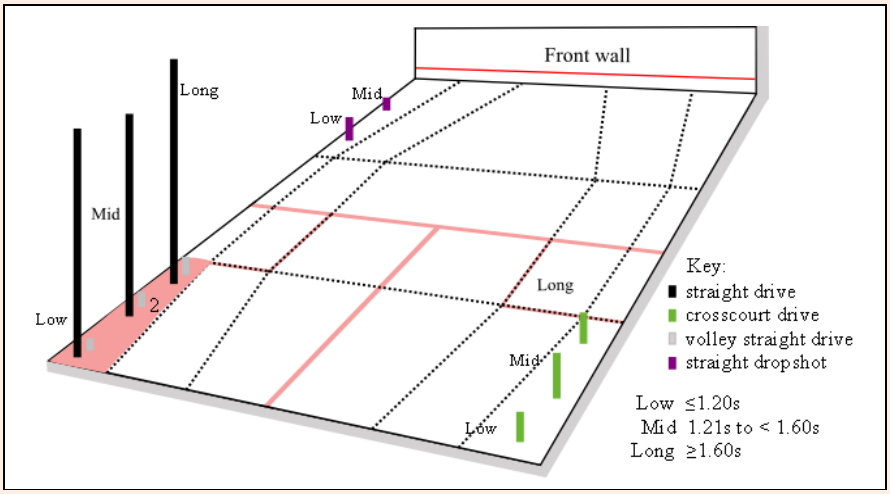

Figure 4. **Percentage occurrence of shot types for area 2 determined by the time interval in relation to the previous shot.**

volleyed short whereas the slower straight drives on the left side of the court may allow these shots. This is speculative but logical and suggests analysis of the availability of time to play a shot may facilitate a deeper understanding of decision-making in racket sports. In the front left area there was a high proportion of straight drop shots (33.42%) and crosscourt lobs (27.63%) which compares well with Murray & Hughes (2001) but was unique to this area of the court. Logically these two shots are indicative of having low time pressure and playing an attacking shot (drop shot) or being under time pressure and playing defensively (lob). This would seem to suggest that time is the critical determinant of shot selection although the area of the court also determines which shot is played.

When the time available to play a shot was considered it was evident that shot selection exhibited both variance and invariance (McGarry and Franks, 1996). In area 2 (back left corner) players predominately played straight drives irrespective of the time available suggesting that at the elite level players are able to play the straight drive under any time constraints. This is indicative of players being able to maintain a general strategy of keeping the opponent in the back of the court using a relatively invariant shot pattern. However other shots were used, including straight drop shots when there was less than 1.6s between shots, suggesting variant behaviour was possible. It is likely that this shot selection was due to tactical choices (Gréhaigne and Godbout, 1995) regarding issues such as positioning in relation to the ball, outcomes from previous rallies, game and match score, physical condition etc. A further factor, which is suggested as being an important determinant for shot selection, is the positions of the two players at the time a shot is being played (Gréhaigne and Godbout, 1995). Players only played straight drop shots from area 2 when there was less than 1.6s between shots because when the between shot time is small the opponent has less time to get to the T area and hence may be out of position. In this situation it is advantageous to play an attacking shot whereas when the between shot time is large the opponent has plenty of time to get into the optimum position and hence the attacking shot is risky and, as shown in this situation, not played by elite players.

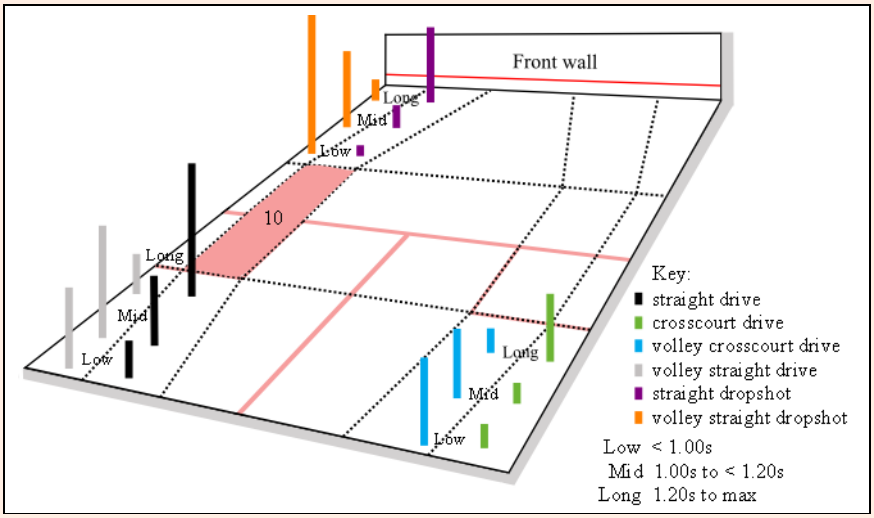

Figure 5. **Percentage occurrence of shot types for area 10 determined by the time interval in relation to the previous shot.**

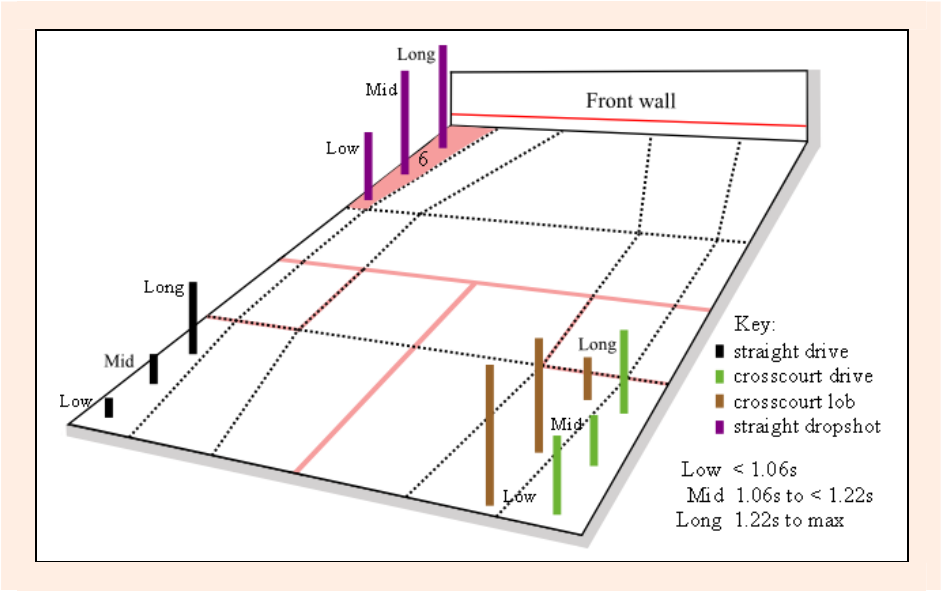

Figure 6. Percentage occurrence of shot types for area 6 determined by the time interval in relation to the previous shot.

Results showed that there were differences in tactics according to the between shot time with 70% of shots played from area 10 aimed towards one of the two back corners in the mid and high time zones, whereas when the ball was taken early the frequency of shots to the front of the court increased to about 40%. This is a similar finding to the shot selections in area 2 where when the between shot time was small there was an increased tendency to play attacking shots e.g. straight drop shot. However in this middle area of the court, players can influence the between shot time, by choosing to volley the ball. This creates pressure for the opponent by both reducing the time available to return the shot and by hitting to three different corners causes uncertainty and prevents anticipatory behaviour.

When players hit the ball in the front of the court, area 6 in this analysis, it is usually, although not always, in response to an attacking shot by the opponent. Consequently in situations where the between shot time was low (< 1.06s) the player was likely to hit a cross court shot, particularly lobs, to relieve the pressure and allow time to get back to the T area whereas when there was more time available the lob was seldom used. When more time was available (> 1.06s) the frequency of straight drop shots increased (by about 10%) suggesting that more attacking options were being played. Indeed this area might seem to be the easiest to predict where a player might hit the ball, since typically only two shots were played when there was a low between shot intervals. However when more time was available players also used the more attacking drives (cross court and straight) and consequently three target areas have to be covered by the opponent. Thus it can be said that hitting the ball into this front area of the court could be deemed risk or reward in that a well-played shot forces the opponent into playing one of two shots whereas a less well placed shot allows the opponent to hit into three main areas.

This study combined shots played by different players in different situations e.g. when losing or winning. This may mask tactical differences in shot selection between different players e.g. predominately attacking versus defensive players and tactical changes adopted within matches as a consequence of the match status (score-line) or the opponent's playing strategy. A further consideration not examined in this paper was the preceding shot type. This is likely to influence a player's shot selection because this indicates the opponent's initial court position and largely dictates the time between shots.

Conclusion

Some elements of a general playing strategy were evident e.g. predominately hitting to the back left of the court, but tactical differences in shot selection were also evident on the basis of court location and time available to play a shot. It was shown that as the time a player had to play a shot decreased the variation in shots played also decreased. The greatest variations in shot selection were found when shot times exceeded about 1.2s. In agreement with McGarry and Franks (1996) both variant and invariant behaviour have been shown to exist in elite squash although for the first time it is suggested that the availability of time to play the shot contributes to the extent to which of these behaviours is evident. In terms of invariant behaviour i.e. a playing pattern, it is pertinent to note that this was found despite the fact that the 10 matches analysed involved 15 different players, suggesting that typical responses can be identified although this is most common when players have small response times (<1.2s).

Further research could repeat these analyses with one player as the participant to examine whether there is an increase in invariance due to individual differences in strategy and tactics. This paper did not consider the preceding shot type which may further help discover invariance. It may also be the case that the availability of time is related to winners and errors. For example winners may be a consequence of playing the ball early (volleying) or accurately and thus giving the opponent very little time to return the ball.

Acknowledgements

The study was conducted within the framework of the research programme 'Kinesiology of Monostructural, Polystructural and Conventional Sports' led by Prof. Milan Čoh.

References

Gréhaigne, J.K. and Godbout, P. (1995) Tactical knowledge in team sports from a constructivist and cognitivist perspective. *Quest* **47**, 490 - 505.

Hong, Y, Robinson, P.D., Chan, W.K., Clark, C.R. and Choi, T. (1996) Notational analysis on game strategy used by the world's top male squash players in international competition. *The Australian Journal of Science and Medicine in Sport* **28**, 18-23.

Hughes, M. and Robertson, C. (1998) Using computerised notational analysis to create a template for elite squash and its subsequent use in designing hand notation systems for player development. In: *Science and Racket Sports II.* Taylor & Francis. London. 227-234.

McGarry, T. and Franks, I.M. (1994) A stochastic approach to predicting competition squash match-play. *Journal of Sports Sciences* **12**, 573-584.

McGarry, T. and Franks, I.M. (1995) Modelling competitive squash performance from quantitative analysis. *Human performance* **8**, 113-129.

McGarry, T. and Franks, I.M. (1996) In search of invariant athletic behaviour in sport: An example from championship squash match-play. *Journal of Sports Sciences* **14**, 445-456.

Murray, S. and Hughes, M. (2001) Tactical performance profiling in elite level senior squash. In: *Pass.com: Computer Science and Sport III and Performance Analysis of Sport V*. CPA, UWIC. Cardiff. 185-194.

Perš, J., Bon, M., Kovačič, S., Šibila, M. and Dežman, B. (2002) Observation and analysis of large-scale human motion. *Human Movement Science* **21**, 295-311.

Vučković, G., Dežman, B., Erčulj, F., Kovačič, S. and Perš, J. (2003) Comparative movement analysis of winning and losing players in men's elite squash. *Kinesiologia Slovenica* **9**, 74-84.

Vučković, G., Dežman, B., Kovačič, S. and Perš, J. (2005) Position error analysis of Sagit/squash system in manual stroke annotation. In: *Book of Abstract* of *10th Annual Congress of the European College of Sport Science*, *Belgrade-Serbia*. 265.

Vučković, G., Perš, J., James, N. and Hughes, M. (2008) Automated tracking system assessments of player distances from the T at the moment the ball is hit for winners and losers of games in elite squash. In: *Proceedings of the World Congress of Performance Analysis of Sport VIII*, *Magdeburg- Deutschland*. 339-344.

Vučković, G., Perš, J., James, N. and Hughes, M. (2009) Tactical use of the T area in Squash by players of differing standard. *Journal of Sports Sciences* **27**, 863-871.

Vučković, G., Perš, J., James, N., and Hughes, M. (2010) Measurement error associated with the Sagit/squash computer tracking software. *European Journal of Sport Science* **10**, 129-140.

Key points

- Previous research has suggested that a playing strategy, elements decided in advance of the match, may be evident for elite players by examining court location and preceding shot type, however these parameters alone are unlikely to be sufficient predictors.
- At present there is no known analysis in squash, or indeed in any of the racket sports, that has quantified the time available to respond to different shot types. An understanding of the time interval between shots and the movement characteristics of the player responding to different shots according to the court positions might facilitate a better understanding of the dynamics that determine shot selection.
- Some elements of a general playing strategy were evident e.g. predominately hitting to the back left of the court, but tactical differences in shot selection were also evident on the basis of court location and time available to play a shot**.**

AUTHORS BIOGRAPHY

Goran VUČKOVIĆ
Employment
Assistant Professor at the University of Ljubljana, Faculty of Sport, Slovenia.
Degree
PhD
Research interests
Performance and Time-Motion Analysis in different sports.
E-mail: goran.vuckovic@fsp.uni-lj.si

Nic JAMES
Employment
Head of research for the London Sport Institute at Middlesex University, London.
Degree
Professor
Research interests
Performance Analysis - profiling performance, momentum, performance indicators, reliabilty, automatic tracking of movement. Sports Psychology - situation awareness, anticipation, decision making, motor skills. Main sports studied - soccer, rugby, squash, golf
E-mail: n.james@mdx.ac.uk

Mike HUGHES
Employment
Visiting professor for the London Sport Institute at Middlesex University, London.
Degree
Professor
Research interests
Performance analysis, science in racket sports, football, rugby, time-motion analysis.
E-mail: mikehughes@data2win.org

Stafford MURRAY
Employment
Head of Performance Analysis and Biomechanics for the English Institute of Sport.
Degree

MSc
Research interests
Performance Analysis and Time-Motion Analysis in racket sports.
E-mail: Stafford.Murray@eis2win.co.uk

Goran SPORIŠ
Employment
Associate Professor at Faculty of Kinesiology, University of Zagreb.
Degree
PhD
Research interests
Theory of kinesiology, performance analysis, sports and exercise nutrition and supplementation, physiological testing of the high-performance athlete, soccer science and medicine.
E-mail: goran.sporis@kif.hr

Janez PERŠ
Employment
Assistant Professor at the Faculty of Electrical Engineering, University of Ljubljana, Slovenia.
Degree
PhD
Research interests
Computer vision, pattern recognition, human motion analysis.
E-mail: janez.pers@fe.uni-lj.si

✉ **Goran Vučković**
Faculty of Sport, University of Ljubljana, Ljubljana, Slovenia