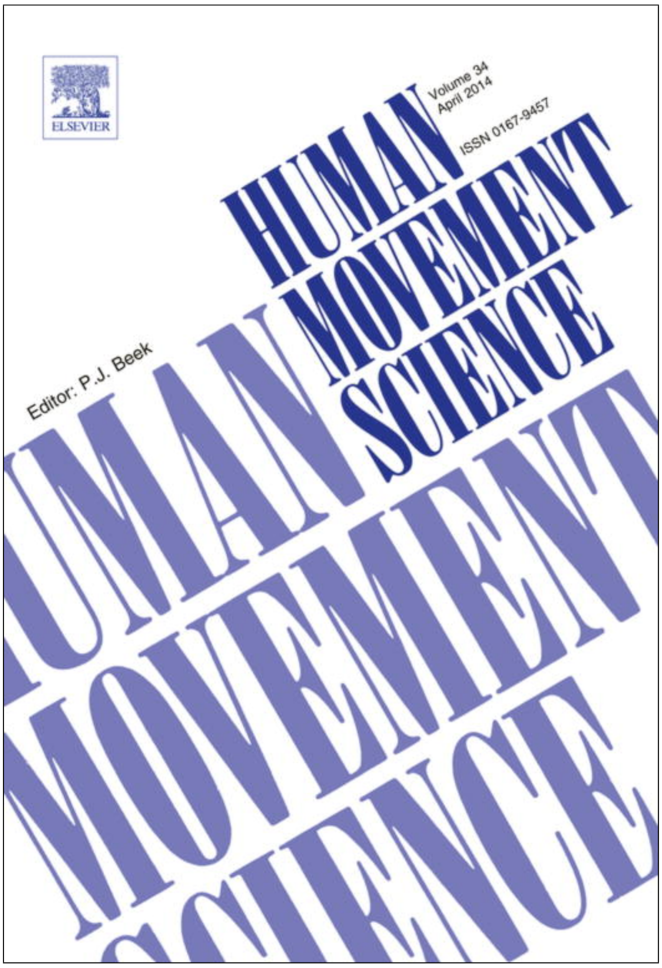
ELSEVIER
Volume 34
April 2014
ISSN 0167-9457
HUMAN MOVEMENT SCIENCE
Editor: P.J. Beek

Human Movement Science 34 (2014) 81–90

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

A new method for assessing squash tactics using 15 court areas for ball locations

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ARTICLE INFO

Article history:
Available online 16 February 2014

Keywords:
Squash tactics
Ball analysis
Method
Shot types

ABSTRACT

Tactics in squash have typically been assessed using the frequency of different shot types played at different locations on the court either without reference to other relevant information or on the basis of the preceding shot. This paper presents a new squash specific method for categorizing court locations in which the ball was played, a novel techniques for assessing the reliability of this method and presents typical shots responses in these new areas controlled for preceding shot as well as the time between shots and the handedness of the players. Twelve games were viewed using the SAGIT/Squash software and 2907 shots viewed a second time from a video image taken from behind the court with an overall agreement of 88.90% for the court location data and 99.52% for shot type. 3192 shots from 9 matches from the 2003 World Team Championships were analyzed in SAGIT/Squash. In the court areas analyzed between 2 and 7 shot responses were predominant suggesting tactical patterns were evident. This was supported by differences evident between shot responses played from the two back corners where the backhand side was characterized by a predominance of straight drives whereas straight and crosscourt drives were played on the forehand side. These results tended to confirm that tactics i.e., consistent shot types, are played although these are only apparent when factors that determine shot selection

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http://dx.doi.org/10.1016/j.humov.2014.01.002
0167-9457/

are accounted for. This paper has controlled for some of these factors but others need to be considered e.g., if individual player profiles are to be ascertained.

1. Introduction

Squash performance is largely characterized by the movement of players and shot selection. The main objective is to move an opponent away from a central area of the court, commonly referred to as the 'T area'. Vučković, Perš, James, and Hughes (2009) found that winners of games tended to spend a greater proportion of time in the T area (a 2×2.8 m area) than losers although this was not evident in closely contested games. The fact that players sometimes failed to position themselves in the T area at the moment when their opponent was playing their shot was thought to be due to shot selection and the accuracy of the shot. However no analysis was undertaken by Vučković et al. (2009) regarding shot types and consequently the implications of playing different shots in different court locations was not investigated.

Previous research has also tried to infer tactical aspects of squash performance using the frequency of different shot types played at different locations on the court (Chan & Hong, 1996; Hong, Robinson, Chan, Clark, & Choi, 1996; Hughes, 1985, 1998). While this can give a general idea of the typical shots played, e.g., county players typically play the ball to the back of the court on the backhand side (Hughes, 1985, 1998), a more comprehensive analysis would also consider the preceding shot (McGarry & Franks, 1996). The preceding shot is likely to be important since some shot types can put an opponent under severe pressure e.g., a hard low accurate drive, whereas other may produce minimal or no pressure e.g., an inaccurate lob gives an opponent lots of time and may be played from the middle of the court. To some extent this relates to the available time for a shot to be played, a factor that has not received much attention in the literature. This type of analysis has the potential for discovering whether players adopt similar strategies irrespective of their opponent i.e., a consistent pattern from specific court locations, or whether they adapt their shot selections as a consequence of trying to limit the effectiveness of their opponent's shots e.g., different patterns against different players.

One issue that has seemingly not been debated is the dimension and shape of the cells used for the shot locations. Previous researchers have consistently used 16 rectangular cells of equal dimension with no discussion of their appropriateness. We considered two issues of relevance to the appropriateness of these cell dimensions. Firstly the location of the shot may be more critical near the sidewalls than in the center of the court. Secondly straight and crosscourt shots tend to have different trajectories, particularly when the sidewalls are hit. Consequently this paper presents a case for an alternative method of dividing the court into cells, which takes into consideration squash tactics.

In order to assess the movement and shot characteristics of squash players it is necessary to have a data collection system that can reliably and accurately record these variables (Atkinson & Nevill, 1998). James, Taylor, and Stanley (2007) suggested that reliability in performance analysis concerns the extent to which the event codes reflect what happened in the game and is therefore also an estimate of the accuracy (validity). These event codes can be manually input by the analyst or, using a system like SAGIT/Squash, automatically processed in software. Performance analysis researchers have taken this issue seriously since Hughes, Cooper, and Nevill (2002) presented data to show that 70% of research papers presented at world conferences featuring performance analysis papers failed to present any reliability assessments. This paper prompted researchers to present reliability statistics although debate ensued regarding how this should be achieved culminating in a reliability edition of the International Journal of Performance Analysis in Sport in 2007 where different views were expressed regarding statistical tests to adopt. Consequently researchers today routinely present reliability information, however, one issue presented by Hughes et al. (2002), that a reliability assessment should be at the level of the subsequent analysis, has seemingly not been considered to the same extent. Since a reliability test determines the extent to which errors in data capture are present, the subsequent results can be assessed in relation to the magnitude of these errors. However this is only possible if researchers provide errors rates for each measure separately and not combined into one overall measure of reliability. This detail is not prevalent in the research literature with overall reliability values more usually presented.

This paper will assess the reliability of ball location information input into the SAGIT/Squash performance analysis software (Perš, Bon, Kovačić, Šibila, & Dežman, 2002). This software both tracks player movements and allows input of shot information where both measures can be determined in relation to the ball location at the point of ball striking. This system has been used by (Vučković, Dežman, Erčulj, Kovačić, & Perš, 2003, 2005; Vučković, Perš, James, & Hughes, 2008, 2010) and the reliability of the tracking system reported in Vučković et al. (2010).

This paper will present shot selections in response to where the preceding shot was played from with consideration to the time available to play the shot, using a novel method for splitting the court into cells of irregular shape. The reliability for determining ball location information is assessed using a novel technique.

2. Methods

2.1. Sample of matches and participants

Matches were recorded at the World Team Championships ($n = 11$), the Slovenian National Championships ($n = 11$) and during a local tournament ($n = 15$), all played in 2003. One match was randomly selected from each tournament (12 games in total) for reliability analysis. Only matches played between right handed players ($n = 9$) during the World Team Championships were used for the tactics analysis. Ethical approval for the study was granted by a university ethics committee and informed written consent was obtained from all participants.

2.2. Procedure

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 and a similar camera located on a tripod at ground level behind the court. The camera placement and methodology for getting the video images into SAGIT/Squash for automatic processing with operator supervision has been well documented in Vučković et al. (2009) and the reliability associated with the resultant calculations of distance and speed for each player were published by Vučković et al. (2010). The exact camera location for the overhead camera (both vertically and horizontally) was not deemed important, as subsequent calibration for image capture accounted for its location.

2.3. Automatic tracking of movements and manual coding

Since this research paper was concerned with recording where the shots were played, it was important to assess how reliably this information was captured, particularly since this was manually added to the software. James, Jones, and Hollely (2002) suggested three sources of error for manual coding of events; Operational error: where the observer presses the wrong button to label an event, Observational errors: the observer fails to code an event, and Definitional errors: the observer labels an event inappropriately. Observer error in this study was likely due to the wrong shot type or an incorrect ball location being entered into SAGIT/Squash.

The SAGIT/Squash system has a separate input system 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. To improve the accuracy of this input a separate video recording, taken from behind the court, was used to enable the operator to estimate the height of the ball above the floor at the time of the stroke. This measure was input into SAGIT/Squash so that the software could make a small correction for any perspective distortion caused by the ceiling-mounted camera not always being directly above the ball location. This height information was only used to decrease the perspective error and as such even a relatively coarse estimate by the operator was sufficient to improve, albeit slightly, the software's estimate of ball location. The software then calculated the x and y coordinates of the ball location and then assigned this to one of 15 areas. The logic behind the configuration of these cells was based on two principles. Anecdotally people knowledgeable about squash would suggest that elite players tend to hit the ball closer to the sidewalls more often than less elite players. The data collected using SAGIT/Squash tended to confirm this (Fig. 1).

The reason for this is simple; a ball hit from very close to the sidewall is more difficult than one hit just a short distance away. Elite players are more capable of hitting the ball into the most difficult court areas and tend not to play shots from anywhere near the middle of the court as they are relatively easy to play and thus avoided. On this basis it seems logical that cell dimensions near the sides of the court are far more critical than central areas and hence the area of the cells should reflect this. The second principle considered was the observation that the ball bounces differently when it hits the sidewall and using this sidewall bounce is a deliberate tactic in elite squash. For example a crosscourt shot from the back of the court to the opposite side of the back of the court is often aimed to hit the sidewall somewhere near to the service box to prevent the opponent volleying the ball. This is tactically astute but means that the trajectory of the ball tends to finish further away from the sidewall the nearer the ball gets to the back wall. A similar observation is made at the front of the court where drop shots are aimed at the nick (the join between the floor and the sidewall) as the ball tends to bounce twice relatively quickly (giving the opponent less time) but also the trajectory changes towards the center of the court. On this basis we considered that cells should not be rectangular in the front and back of the court but should represent typical ball trajectories for these areas. The consequent areas used are therefore suggested to distinguish between shots that were played close to the sidewalls (areas 1–6), shots that were played from similar positions but not close to the sidewalls (areas 7–12) and from the middle of the court (areas 13–15).

2.4. Reliability

In order to calculate the reliability for determining the ball location accurately two separate measures were compared. The first was the original SAGIT/Squash derived court area (explained in earlier section) and the second involved the operator viewing the overhead video images and inputting the court locations and shot type for 2907 shots, undertaken over 1 year after the initial data entry to prevent memory effects (operator input). The operator had played squash at an International level, was an International coach and had over 10 years experience of squash analysis. It was important that the operator was as accurate as possible otherwise a low reliability result could have been achieved due to operator error whereas we wanted to assess the reliability of SAGIT/Squash. The comparison between the two measures of data capture (SAGIT and operator) was thought to be adequate to highlight all possible errors of data input with low errors suggesting that the methodology was appropriate. The two assessments of the correct area (SAGIT and operator) were then compared and 7 obvious errors were identified, since the two areas were not adjacent. These errors were attributed to the operator entering the wrong area number as the location had been entered on the wrong side of the court (operational error), not likely when clicking on the image of the ball as during the data input into SAGIT/Squash. These errors were rectified before undertaking Kappa and percentage agreement (number of agreed locations divided by the number of disagreements) calculations. These resulted in an overall

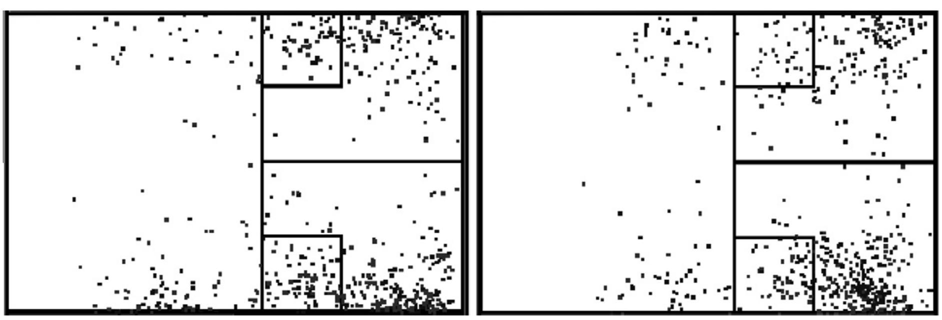


Fig. 1. Example shot location distributions for an elite (left) and National (right) level game.

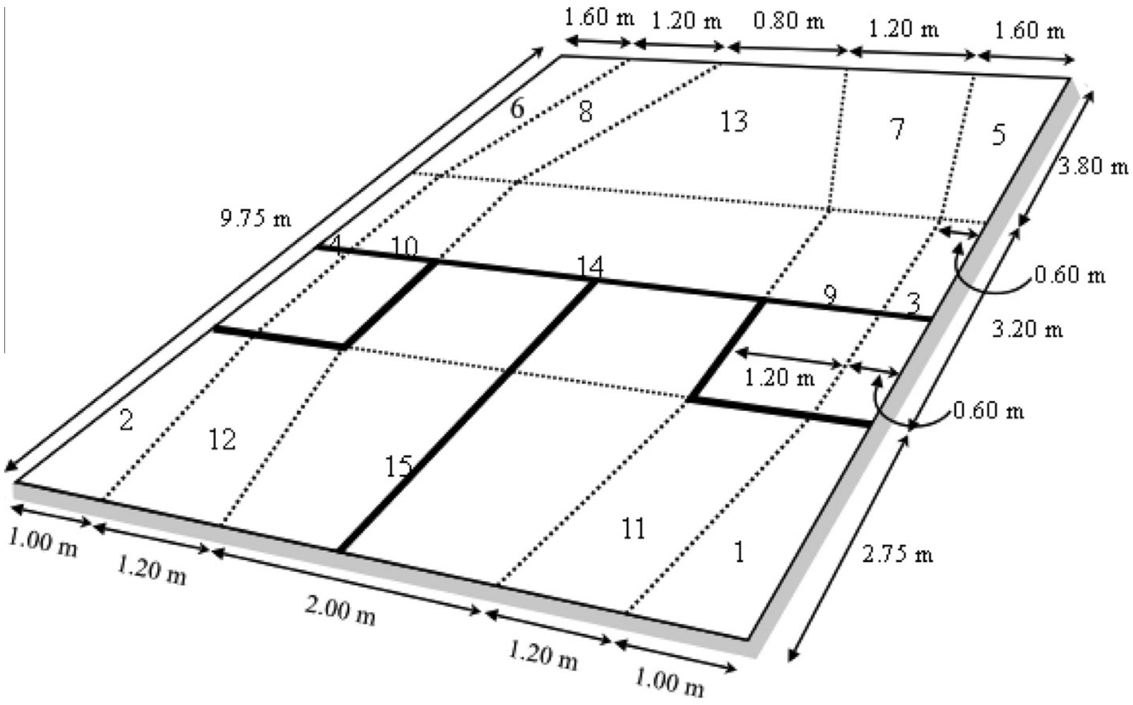


Fig. 2. Dimensions of the court floor divided into 15 areas.

Kappa value of 0.869 and percentage agreement of 88.90% for the court location data and a percentage agreement of 99.52% for shot type data. While the reliability value for shot type was deemed acceptable it was felt that an overall reliability statistic for the court areas could potentially hide problematical locations on the court that could yield unreliable information regarding area location. This could be a problem in that the true cell location could be entered incorrectly due to the proximity of the ball being on or close to the cell boundary. Both SAGIT/Squash and the observer on the reliability test can make this type of observational error. For the reliability test when both agree the true location is assumed and when there is a disagreement the reliability is considered compromised. Of course when a court has lots of cells the frequency of these disagreements increases as the probability of the ball being on a boundary increases. To ascertain the extent to which this was a problem further assessments were carried out to consider areas in pairs. For example, the border between areas 2 and 12 (see Fig. 2) could be problematical for discerning whether the ball was in area 2 or area 12. The extent to which this, and for all other borders, was a problem was ascertained by carrying out Kappa and percentage agreement calculations for each border where the total number of agreements for both areas were used to compare against the number of times one method recorded one area and the other method recorded the other area (two possible situations) and the results presented in Fig. 3.

The possibility of confusion for two adjacent areas joined by a corner e.g., calls 1 and 9, also existed. Calculations for all 16 of these adjacent areas revealed Kappa values of at least 0.98 and percentage agreement of at least 99.45%.

3. Results

For the tactics analysis both court location from which the shot was played and the preceding shot type were considered. However if the preceding shot was a serve then the subsequent shot was not analyzed as it was felt that this was a different situation to shots played later during rallies. In order to produce meaningful shot profiles, reasonable frequencies of shots were required to prevent unusual shots in low frequency situations disproportionately changing the profile. Also if only two or three shots were played from a particular location it was impossible to provide a meaningful assessment of likely shot types. For this reason only shot types that occurred relatively frequently (>4% of total)

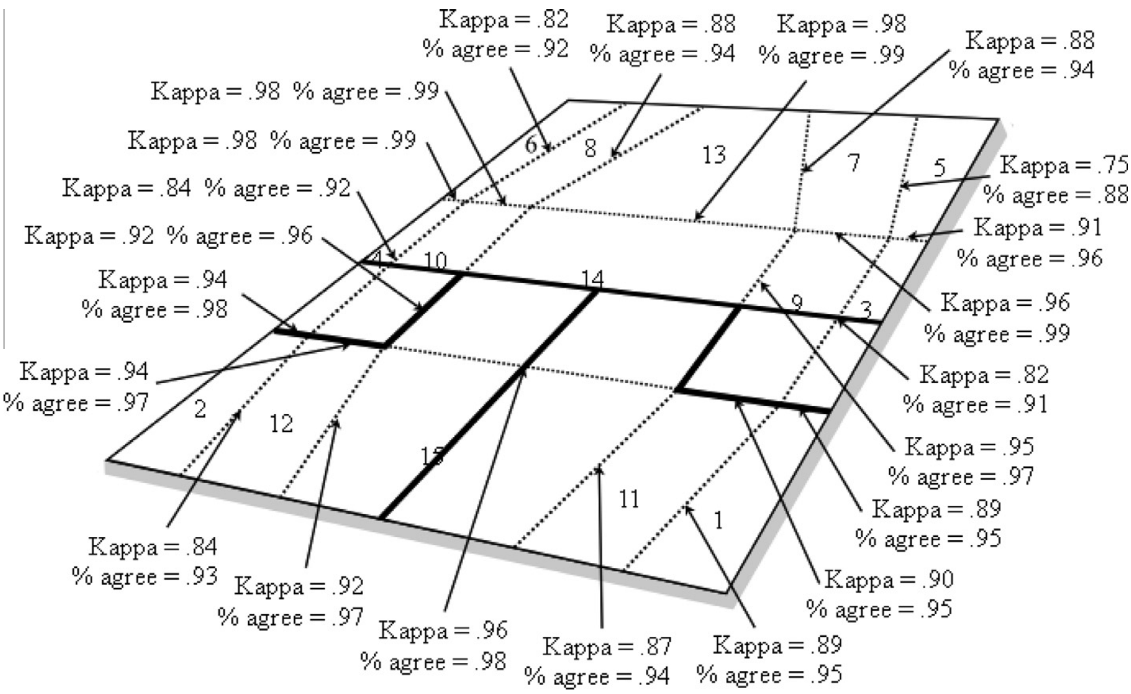


Fig. 3. Reliability statistics for between area accuracy.

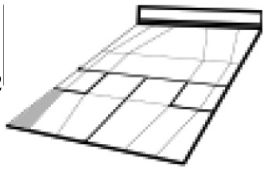
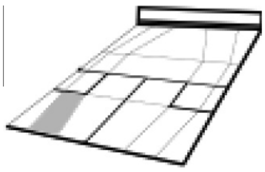
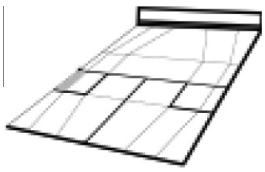
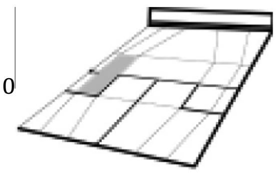
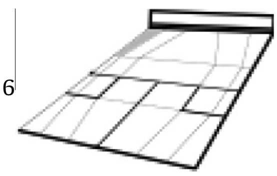
were included and court areas where less than 4% of the total shots were played were excluded for the same reason.

It was thought that tactics may change when playing against left or right handed players and since the matches analyzed contained just two matches involving left handed players these were excluded from the subsequent analysis. A final consideration for determining tactical shot selection was thought to be the time available to play the shot. On this basis, shots played with very little time pressure were excluded as in this situation it was thought that players had the whole range of shots available to them and hence a playing strategy would be impossible to ascertain. The exception to this being a very well placed lob, which gives the opponent time, but because of the accuracy limits the shot response. While all shot situations (time pressure or court location but also player positions and movements) can influence shot selection this research has only selected specific situations, which occur frequently, as exemplars. Through a process of trial and error, shots played more than 1.21 s after the preceding shot was struck, were excluded from this analysis. In a similar manner shots played less than 0.65 s after the preceding shot was struck ($n = 36$) were excluded as they were deemed extreme values when the distribution of times were examined. This process left 3192 shots available for the tactics analysis.

Tables 1 and 2 thus show the most frequent shots played in response to the most prevalent preceding shots in different court areas. Results suggested that in some areas (1 and 2), two shot responses were most prevalent (in response to straight and crosscourt drives) but as many as seven shot responses were possible (to a volley straight drive played to area 4). There appeared to be differences in shot responses depending on the side of the court played from. In the back left corner (area 2) of the court (players' backhand) the straight drive was the predominant shot regardless of the preceding shot, typically straight or crosscourt drive (79% and 87% respectively). In contrast, in the back right corner (area 1) players played both straight (39%) and crosscourt (39%) drives when the preceding shot was a straight drive but predominately straight drives (68%) following crosscourt drives. Similar tactics were seen in the areas adjacent to the back corners although on the left side (area 12) crosscourt drives were more prevalent (than area 2) and the incidence of straight drops also increased. On the right side of the court (area 11) a tactical difference appeared to be evident when the preceding shot was a crosscourt drive with crosscourt drive responses more prevalent (40%) than for area 1 (19%).

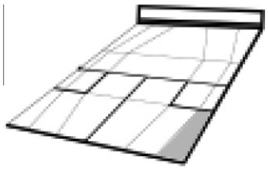
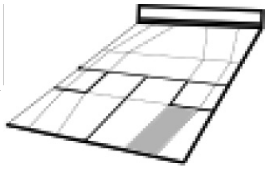
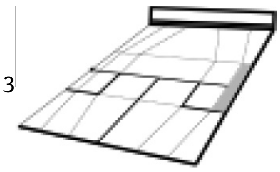
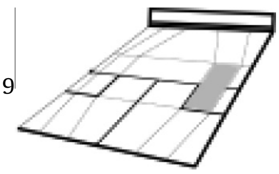
The greatest variation of shot responses, and preceding shot types, was evident in the middle areas of the court. When the preceding shot was tight i.e., shot responses from areas 3 and 4, the preceding

Table 1
Percentage of shots played from different areas of the left side of the court in response to the most frequent types of previous shot.

Area	Preceding shot	Shot response played in area	Percentage (%)
2 	St drv (76%)	St drv (79%); Xcourt drv (9%)	88
	Xcourt drv (12%) (Sample = 88%)	St drv (87%); Xcourt drv (7%)	94
12 	St drv (36%)	St drv (60%); Xcourt drv (16%); St drop (10%)	86
	Xcourt drv (47%)	St drv (63%); Xcourt drv (13%); St drop (8%)	84
	V Xcourt drv (13%) (Sample = 96%)	St drv (70%); Xcourt drv (22%)	92
4 	St drv (51%)	St drv (10%); V Xcourt drv (27%); V St drv (29%); V St drop (24%)	90
	V St drv (10%)	St drv (28%); Xcourt drv (11%); V Xcourt drv (13%); V St drv (17%); St drop (9%); V St drop (11%); Xcourt lob (9%)	98
	St dropshot (18%)	St drv (14%); Xcourt drv (22%) St drop (41%); Xcourt lob (22%)	99
	V St dropshot (18%) (Sample = 97%)	St drv e (14%); Xcourt drv (22%) St drop (34%); Xcourt lob (27%)	97
10 	St drv (54%)	V Xcourt drv (24%); V St drv (33%); V St drop (29%)	86
	Xcourt drv (15%)	St drv (19%); Xcourt drv (12%); V Xcourt drv (17%); V St drv (22%); V St drop (27%)	97
	V St drv (11%) (Sample = 80%)	St drv (27%); V Xcourt drv (26%); V St drv (11%); V St drop (31%)	95
6 	St drop (73%)	St drv (9%); Xcourt drv (23%); St drop (30%); Xcourt lob (32%)	94
	V St drop (15%) (Sample = 80%)	St drop (30%); Xcourt lob (58%)	88

Key: St = Straight; drv = drive; V = volley; Xcourt = crosscourt; drop = dropshot.

Table 2
Percentage of shots played from different areas of the right side of the court in response to the most frequent types of previous shot.

Area	Preceding shot	Shot response played in area	Percentage (%)
1 	St drv (77%)	St drv (39%); Xcourt drv (39%)	78
	Xcourt drv (11%)	St drv (68%); Xcourt drv (19%)	87
	V St drv (10%) (Sample = 98%)	St drv (59%); Xcourt drv (26%); St drop (11%)	86
11 	St drv (38%)	St drv (44%); Xcourt drv (39%)	83
	Xcourt drv drv (40%)	St drv (35%); Xcourt drv (40%); 3 wall boast (14%)	89
	V Xcourt drv (13%) (Sample = 91%)	St drv (29%); Xcourt drv (43%); St drop (14%)	86
3 	St drv (48%)	St drv (15%); Xcourt drv (26%); V Xcourt drv (37%); V St drv (11%)	89
	Xcourt drv drv (10%)	St drv (25%); Xcourt drv e (31%); V Xcourt drv (31%)	87
	V St drv (14%)	V Xcourt drv (18%); St drop (14%); Xcourt lob (9%)	95
	V St dropshot (14%) (Sample = 86%)	St drv (10%); Xcourt drv (43%) St drop (19%); Xcourt lob (24%)	96
9 	St drv (24%)	St drv (25%); Xcourt drv (20%); V Xcourt drv (19%); V St drv (9%); V St drop (17%)	90
	Xcourt drv (30%)	St drv (13%); Xcourt drv (13%); V Xcourt drv (38%); V St drv (21%); V St drop (11%)	96
	V Xcourt drv (23%)	V Xcourt drv e (43%); V St drv (25%); St drop (11%); V St drop (11%)	90
	V St drv (10%) (Sample = 87%)	St drv (39%); Xcourt drv (21%) V Xcourt drive (18%); St drop (15%)	93

Key: St = straight; drv = drive; V = volley; Xcourt = crosscourt; drop = dropshot.

shot tended to be a straight drive (48% into area 3 and 51% into area 4). Shot responses however, tended to be straight (63%) shots (straight drive, volley straight drive and volley straight drop) from the backhand side (area 4) whereas crosscourt shots (crosscourt drive and volley crosscourt drive) were more prominent (63%) on the forehand side (area 3). When the preceding shot was not so tight (into areas 9 and 10) no clear pattern of shot responses was evident. In contrast shots responses were typically straight drop shots (30%) or crosscourt shots played to the back of the court (lobs or drives) from the front left corner of the court (area 6).

4. Discussion

Before analyzing any performance some consideration must be given to the methods being used and whether they are sufficiently robust to enable reliable and accurate data collection. When analyzing squash performance, it is typical to divide the court into areas for analysis but little attention has been devoted to the size and shape of these areas. A new approach was presented which was based on the area of the court and bounce of the ball in squash and a new method for determining the reliability associated with each cell presented. Since the percentage agreement was shown to be typically around 95% or higher it was suggested that this was an acceptable method for squash analysis. This compares very favourably with McGarry and Franks (1996) who found a weighted Kappa coefficient greater than 0.8 when comparing the same operator assessing 60 rallies using the traditional 16 rectangular cells for court location with a six week gap between analyses.

The distributions of shot types found in this study were not directly comparable with previous studies because of the difference in cell shapes and sizes. However changing the cell dimensions was thought necessary as the previous 16 rectangular cell method didn't distinguish between shots that were played close to the sidewalls (labeled areas 1–6 in this paper) from shots that were played from similar positions but not close to the sidewalls (areas 7–12). Future studies are needed to fully test whether this logic is an improvement over the previous method but these results have shown that squash tactics can be reliably discerned.

In order to determine the extent to which typical shot responses could be determined this study selected shots under strict conditions. This was in response to McGarry and Franks (1996) who suggested that invariant patterns of play were difficult to ascertain but who also pointed out that the preceding shot alone is likely to be insufficient to predict the subsequent shot. Consequently a number of conditions were required before the shot response was considered in this paper. Previous shot type, time between shots, court location and the handedness of the players were controlled to reduce the number of factors that would be likely to determine shot selection. Having done this the results suggested that in some areas (tight back left and right corners) players were highly likely to play one of two shot responses when the preceding shot was a straight or crosscourt drive. If the ball was not so tight (the adjacent areas 11 and 12) the shot responses tended to become more varied. Further analysis of shot responses in other areas of the court tended to back up this finding with tight shots (responses from close to the corners of the court) tending to be more predictable (two or three typical shots played) than loose ones (up to seven different shot responses to the same preceding shot when nearer the middle of the court). However there also appeared to be tactical differences based on the side of the court the shot was being played from with a tendency to play the ball towards the back left of the court (to the right handed player's backhand). This was evident for the back and middle areas of the court only, as shot responses at the front of the court appeared to utilize the diagonal of the court i.e., shots were played to the opposite sides of the front and back of the court.

5. Conclusions

This paper has provided a novel method for splitting the squash floor area into cells for shot analysis. The cells were determined by the knowledge of how the ball typically bounces and the logic of using the proximity of the sidewalls to determine areas that were deemed as tight, loose and down the middle. The subsequent analysis tended to confirm that these areas were discriminating different conditions since shot selections varied between the areas (tactics were thus evident). While this paper has only considered a small subset of conditions under which shots were played, the results tend to suggest that other conditions should be analyzed to determine how well tactics can be determined. For example individual player profiles may be determined, which may be opponent specific. Winning and losing performances may also be analyzed to assess tactical profiles in favorable and unfavorable situations. In summary this paper presents a more detailed approach to analyzing tactics by controlling for a number of variables although further research is required to determine the extent to which these and other factors affect shot selection.

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