Effects of rule changes on physical demands and shot characteristics of elite-standard men's squash and implications for training

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Abstract

The physical demands and rally characteristics of elite-standard men's squash have not been well documented since recent rule changes (scoring and tin height). This information is needed to design optimal training drills for physical conditioning, provided here based on an analysis of movement and shot information. Matches at the 2010 (n = 14) and 2011 (n = 27) Rowe British Grand Prix were analysed. Rallies were split into four ball-in-play duration categories using the 25th (short), 75th (medium), 95th (long) percentiles (long) and maximum values. Cohen's d and Chi squared tests of independence evaluated effects of rally and rule changes on patterns of play. The proportion of long, middle and short shots was related to the duration of the rally with more shots played in the middle and front of the court in short rallies (phi = 0.12). The frequencies of shots played from different areas of the court have not changed after the adoption of new rules but there is less time available to return shots that reflects the attacking nature of match play for elite-standard men players. Aspiring and current elite-standard players need to condition themselves to improve their ability to cope with these demands using the ghosting patterns presented that mimic demands of modern match play.

Key words: Game characteristics; shot placement; training protocol

Introduction

Specific training and practice is necessary to condition athletes optimally for performance (Reilly, Morris, & Whyte, 2009). Hence, there is a need to improve understanding of match characteristics of a sport at the standard of participation (Murray and Hughes, 2001). In squash, previous research has identified demands of match play at different playing standards, although changes to the scoring system and tin height could have altered patterns of play.

Squash was first analysed by Sanderson and Way (1977) using hand notation to record the frequency and distribution of winning shots and errors. Hughes (1985) computerised this system and identified tactical differences among club-, county-, and national-standard players, partially attributed to

different movement capabilities. For elite-standard men's squash, Hughes and Robertson (1998) described typical match characteristics (e.g. rallies had a mean duration of 21 s), using a sample of five matches that involved players ranked in the world's top 20. While this provided detailed information of the matches analysed, the usefulness of simple means for training purposes was limited, particularly since these types of data tend to be non-normal in their distributions.

Girard, Chevalier, Habrard and Millet (2007) presented rally durations in 3 s intervals up to 24 s, then 6 and 10 s intervals followed by all other rallies grouped for durations over 40 s. These time intervals were selected from a physiological perspective but this might not be ideal from tactical and training perspectives. Similarly Vučković and James (2010) used four categories (0 to 3.9 s, 4 to 11.9, 12 to 24.9 and 25 and over) but, for training, the first category was too short and the last was too long.

Player movements were first analysed using a manual tracking system on a computerised digitisation pad to assess speed, accelerations, and distances (Hughes & Franks, 1994). More recently, a reliable semi-automated computer vision tracking system for squash (Vučković, Perš, James, & Hughes, 2010) was developed. The SAGIT/Squash system was initially used to assess movement in the 'T' area of the court (Vučković, Perš, James, & Hughes, 2009). Winning players spent a greater proportion of total playing duration in the T area than losers. However individual match analysis has been suggested as not being the most appropriate measure for determining differences in performance between winners and losers because it is often the case, particularly in close matches, that the losing player wins a high proportion (nearly 50%) of the rallies (Vučković, Dežman, Erčulj, Kovačič, & Perš, 2004).

Vučković et al. (2014) used a new squash-specific method for categorising court locations in which the ball was played to present typical shots responses for elite-standard players. These responses depended on position on court and the duration between shots (Vučković et al., 2013). The studies used squash matches played under the 9 point-on-serve (POS to 9) rules with a 48.3 cm high tin (line on front wall that is out of play). In 2009, the World Squash Federation and the Professional Squash Association aligned to standardise all professional men's squash matches to play to 11 point-per-rally (PPR to 11) with a 43.2 cm tin. A comparison of elite-standard squash matches played under the two systems found the number of rallies had reduced from a median of 34 (IQR = 15) to 20 (IQR = 8) although the duration of rallies had not

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changed (Murray, James, Dineen, Hughes, & Vučković, 2013). Mean match duration, distance covered and speed had also reduced under the new system although these results were based on a small sample size (10 matches under the new rules).

The aim of this paper was to present general match and physical characteristics for PPR to 11 squash (43.2 cm tin) and more detailed rally information such that specific training could be devised. This included presenting more informative descriptive statistics than just measures of central tendency and dispersion, to improve the specification of appropriate training.

Methods

Matches at the 2010 (n = 14) and 2011 (n = 27) Rowe British Grand Prix, held in Manchester, UK were recorded and processed using Tracker software (Perš, Kristan, Perše, & Kovačič, 2008) that is a newer version of the SAGIT/Squash software (Vučković et al. 2009). Thirty four full-time professional players of mean age 27.7 years (SD = 3.85) who were ranked in the world's top 75 participated. A further 11 matches with players ranked in the top 16 in the world were analysed to obtain POS to 9 comparison data (as used in Vučković et al. 2009). Ethics approval for the study was provided by the sports science sub-committee of Middlesex University's ethics committee. No external agencies were involved with data collection, analysis or interpretation and have no rights regarding the publication of this research.

Matches took place on a court set up with a PAL video camera (Sony HDV handy camera HVR-S270, Japan) with a specially adapted 16 mm wide angled lens (Sony NEX SEL16F28) attached to the ceiling above the central part of the court to make all of the floor plus some of the walls visible. A similar camera (used by the Professional Squash Association to record matches) was located on a tripod 15 m behind the court and 5 m above ground level. The camera placement and techniques for transferring video images into Tracker were identical to SAGIT/Squash i.e. automatic processing with operator supervision, and have been well documented (Vučković et al., 2009) along with the reliability for resultant calculations of distance and speed for each player (Vučkovićet al., 2010) and positions on court (Vučković et al., 2009). The exact camera location for the overhead camera (both vertically and horizontally) was not critically important, as subsequent calibration for image capture accounted for its position.

General match information and shot distributions were calculated to facilitate comparison with previous research on matches that used the old scoring system (data from Vučković et al., 2013; Vučković et al., 2014). This included both game and rally information to improve a common training routine called ghosting i.e. players imitate rally movements without striking a ball as a solo drill. Rallies needed to be categorised according to duration, movement locations and physiological demand e.g. exercise-to-rest ratios. Previously presented rally duration intervals of 3 (Girard et al., 2007) and 4 s (Vučković & James, 2010) were considered too short for training purposes and longer rally durations had not been considered fully (Vučković & James, 2010). The distribution for rally durations was positively skewed so rallies were split into four categories using the 25th (short), 75th (medium), 95th (long) percentiles and maximum values (very long) as the upper values for each rally duration category. Match characteristics were then calculated to inform the prescription of ghosting schedules. This analysis resulted in matches being categorised according to the World rankings of the players as this was related to match duration.

Statistical analysis was performed using IBM SPSS software (version 21.0; SPSS Inc., IL). The data were assessed for normality (Shapiro-Wilks' test) and the skewed distributions specified that the median and interquartile range were used to describe them. Game and rally duration, number of rallies, player distance and speed and shot distributions were calculated for rallies categorised by their duration. Cohen's d (Cohen, 1988) was used to assess the magnitude of differences between distances covered by rally winners and losers, evaluated as trivial (0-0.19), small (0.20-0.49), medium (0.50-0.79) and large (0.80 and greater) (Winter, Abt, & Nevill, 2014). Chi squared tests of independence tested whether the proportion of long (to the back of the court), middle and short (front) shots were related to the duration of the rally and whether the distribution of shots had changed under the new rules. Statistical significance was set at $p < 0.05$.

Results

Games played under the PPR to 11 rules have reduced in length (median = 11 min 37 s) compared with POS to 9 (Table 1) as there were typically fewer rallies per game (median = 21) and hence less distance covered

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by players. However game duration varied between 4 and 32 min. Individual rally characteristics have changed slightly with more shots being played in shorter duration than POS to 9.

Table 1: Game and rally statistics for World ranked male squash

| | POS to 9 | | PPR to 11 | |
	Median	*IQR*	Median	*IQR*
Game				
duration	15min 45 s	*8min 26 s*	11min 37 s	*6min 51 s*
ball in play	54.4%	*9.0%*	51.4%	*11.4%*
distance travelled	1054 m	*543*	496.3 m	*292.6*
rallies per game	34	*15*	21	*8*
Rally				
duration	15.0 s	*5.4*	13.2 s	*15.7*
shots	11	*16*	13	*19*
distance travelled	22.1 m	*31.2*	18.8 m	*24.2*
speed	1.5 m/s	*0.1*	1.4 m/s	*0.3*

The frequencies of shots played from the different areas of the court were trivially different between POS to 9 and PPR to 11 (chi-square = 269.98, df = 14, p < .001; phi = 0.08; Figure 1).
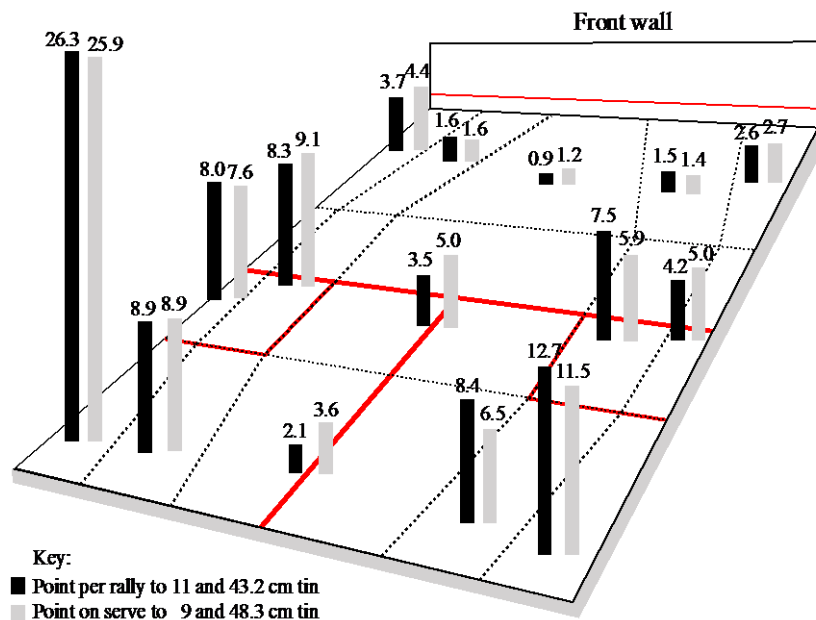

Figure 1: Shot distribution played under point-per-rally to 11 and point-on-serve to 9 rules

The variability in rally characteristics for all matches were presented as medians (for comparisons with previous studies) along with percentiles i.e. upper values for each category (Table 2) to better present the variability (and skewness) for prescribing specific training routines (Table 4). Rally losers covered trivially more distance than winners in 54.4% of the rallies for short (d = 0.09), medium (59.0%; d = 0.09) long (53.7%; d = 0.07) and very long rallies (54.9%; d = 0.04). The proportion of long, middle and short shots was related to the duration of the rally (chi-square = 440.0, df = 6, p < .001; phi = 0.12; Table 2) with fewer shots played in the middle and front of the court as rally duration increased.

Table 2: Descriptive statistics for rallies categorised by duration

		Median	Short 25th percentile	Medium 75th percentile	Long 95th percentile	Very long Maximum
Duration of rally (max for categories)		13.2 s	7.0 s	22.7 s	46.4 s	146.5 s
Shots per rally (max. both players)		13	6	25	42	157
Distance (max. per player)		18.8 m	9.6 m	33.5 m	68.3 m	200.0 m
N rallies per game (max inc. lets)		21	17	25	34	41
Game time		11 min 37 s	9 min 6 s	15 min 57 s	23 min 49 s	32 min 6 s
Mean speed in rally	Winner	1.4 m/s	1.2 m/s (0.4)	1.4 m/s (0.3)	1.4 m/s (0.2)	1.4 m/s (0.2)
	Loser	1.4 m/s	1.2 m/s (0.4)	1.4 m/s (0.3)	1.5 m/s (0.2)	1.4 m/s (0.2)
Mean distance in rally	Winner	18.7 m	5.5 m (4.1)	19.6 m (11.4)	44.7 m (13.5)	90.5 m (28.7)
	Loser	19.4 m	5.8 m (4.8)	20.3 m (11.5)	45.5 m (14.7)	91.6 m (26.9)
Shots played from	Front	10.3%	16.7%	12.5%	9.2%	6.7%
	Middle	31.3%	44.2%	32.4%	30.2%	29.3%
	Back	58.4%	39.1%	55.1%	60.6%	64.0%

Match duration was related to difference in World rankings between the two players (r = -0.65, Figure 2) and usually lasted (including breaks between games and rallies) between 35 and 85 minutes except when played between players with dissimilar World rankings (around 40 or more) where much shorter durations occurred (Table 3 and Figure 2).
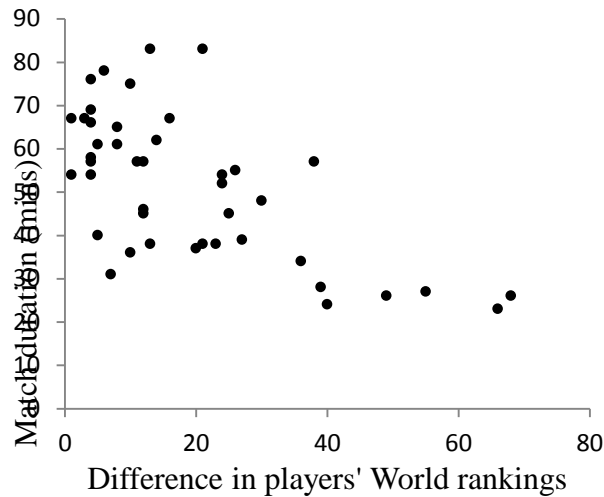

Figure 2: Match duration against difference in player ranks

For similarly ranked players (less than 40 ranking points difference), players tended to move a median of 2 km in about 23 minutes ball-in-play duration, split into 80 rallies each lasting 17 s.

Table 3: Match statistics (median and *IQR*) for different levels of World ranked male squash players

| | All matches | Difference between players' World ranking | | | |
		0 to 10	11 to30	0 to 39	40 or more
N	41	16	17	36	5
Match duration	54 min *(25.5)*	61 min *(13.0)*	50 min *(16.5)*	56 min *(24.5)*	26 min *(2.0)*
Ball in play	22 min *(10.3)*	25 min 12 s *(8.1)*	23 min 18 s *(7.2)*	23 min 48 s *(8.6)*	11 min 30 s *(1.7)*
Distance (ball in play)	1848.7 m *(1045.7)*	2218.1 m *(796.0)*	1848.7 m *(788.8)*	1995.7 m *(829.4)*	953.1 m *(120.3)*
Number of rallies	77 *(29)*	85 *(22)*	80 *(23)*	82 *(25)*	51 *(2)*
Rally duration	13.2 s *(15.7)*	13.1 s *(15.7)*	13.6 s *(16.8)*	13.3 s *(15.9)*	11.4 s *(13.7)*

Table 4 presents the ghosting patterns for the different rally and game durations presented in Table 2. Rest periods of 14 s were used (except after short rallies where 5 s was allowed) to replicate normal between-rally durations (median = 13.7 s).

Table 4: Number of ghosting repetitions required to mimic frequency, duration and number of shots for rallies in elite male squash.

	Short rally (7 s)	Medium rally (23 s)	Long rally (47 s)	Very long rally (160 s)	Number of repetitions
Ghosting pattern	1 x front 2 x side 2 x back	2 x front 4 x middle 6 x back	2 x front 6 x side 12 x back	6 x front 24 x side 48 x back	
Short game (9 minutes)	4	7	4	0	15
Medium game (16 minutes)	6	11	5	1	23
Long game (24 minutes)	9	18	8	1	36
Very long game (32 minutes)	12	24	9	2	47

Discussion

The new PPR to 11 rules (scoring and tin height) have reduced the possibility of rallies not resulting in a point (Lets are still possible), hence, the number of rallies and distance covered have reduced considerably. These shorter game durations, with reduced tin height, indicate that players have changed their shot strategies to take advantage of these easier (physical and environmental) conditions. However, this research revealed that elite-standard men players were hitting the ball to similar areas of the court under the new rules compared to the old but more to the front of the court in shorter rallies than longer ones. These short shots are symptomatic of an attacking strategy as the duration available to return this type of shot is typically less than for shots played to the back of the court. It is not clear if this is a consequence of the new

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rules, but rally durations were slightly shorter (median = 13.2 s) for PPR to 11 than for POS to 9 (median = 15.0 s) while the number of shots had increased to a median of 13 from 11. Aspiring and current elite-standard players need to condition themselves to cope with the physical demands associated with these rally characteristics. However future research also needs to assess these changes in greater detail to determine the duration between shots for different types of shot, as it is likely that some types will force an opponent to play quicker and thus have less time. This is an important consideration for training to ensure that match play intensities are correctly replicated in training.

While specificity of training is commonly regarded as essential for the conditioning of elite athletes (Reilly et al., 2009), there has been a lack of direction from the scientific literature in some sports. In squash, most research papers have presented mean values for shot (Murray & Hughes, 2001; Hughes & Robertson, 1998), movement (Hughes & Franks, 1994) and match (Murray & Hughes, 2001) characteristics that provide descriptions, but do little to help players devise appropriate training programmes. This study found that distances travelled were mainly a consequence of rally duration (very large effect size), although rally outcome had a trivial effect (partial eta squared = 0.02), with rally winners travelling less distance than losers. On this basis, rally durations were categorised as short, medium, long and very long using 25th, 75th, 95th percentiles and the maximum value obtained in the sample. These four categories were selected so that ghosting routines could be prescribed in a similar ratio as they tended to occur i.e. 5:10:4:1 (up to 25th percentile, up to 75th percentile, 90th percentile and the final 10%).

The first shot for each player requires little movement (return of serve player is stationary and server walks to T after serving). This has more effect on players' speed for short rallies but the influence diminishes as the number of shots in a rally increases. Hence short rallies had lower speeds than the other rally categories, but for training, this is unimportant. Similarly, differences in speed and distance between winning and losing players were small, and less apparent as rally durations increased, and trivial for training

Rally duration had only a small effect on the proportion of shots to the front, middle and back of the court with the clearest difference being for short rallies, which had a greater proportion of shots in the front and middle of the court than other rally categories. This suggested an increased proportion of volleys and

the need for a slightly different movement pattern when replicating these rallies. On this basis, movement patterns were presented for short, medium, long and very long rallies with the number of repetitions calculated such that short, medium, long and very long games could be replicated. It is envisaged that players interested or currently playing at elite standard can use these protocols to replicate match durations of their choice (using information from Table III).

Conclusion

The new rules (scoring and tin height) have reduced the time elite-standard men have to perform shots. Aspiring and current players of this standard need to condition themselves to cope with these demands. This paper has presented a ghosting protocol that replicates the movement patterns for short, medium, long and very long rallies with the number of repetitions calculated such that short, medium, long and very long games could be replicated. Future studies should determine differences in rally characteristics with greater resolution e.g. duration between shots for different types of shot and for different players based on world ranking or playing style.

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