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FITZPATRICK, Anna, STONE, Joseph <<http://orcid.org/0000-0002-9861-4443>>, CHOPPIN, Simon <<http://orcid.org/0000-0003-2111-7710>> and KELLEY, John <<http://orcid.org/0000-0001-5000-1763>>

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**Title Page**

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**Important performance characteristics in elite clay and grass court tennis match-play.**

Anna Fitzpatrick<sup>a\*</sup>, Joseph Antony Stone<sup>b</sup>, Simon Choppin<sup>a</sup>, & John Kelley<sup>a</sup>

<sup>a</sup>Centre for Sports Engineering Research, Sheffield Hallam University, UK

<sup>b</sup>Academy of Sport and Physical Activity, Sheffield Hallam University, UK

ORCIDs: Anna Fitzpatrick 0000-0001-7907-2303, Joseph Antony Stone 0000-0002-9861-4443

\*Correspondence concerning this article should be addressed to Anna Fitzpatrick, S001 Chestnut Court, Sheffield Hallam University, Collegiate Crescent, Sheffield, S10 2BP, UK. Tel: +44 114 225 2355; E-mail: anna.fitzpatrick@shu.ac.uk

14 **Important performance characteristics in elite clay and grass court**  
15 **tennis match-play.**

16 **Abstract**

17         The performance characteristics of elite tennis match-play differ depending on  
18 court surface. However, the performance characteristics (e.g. aces, first serve points won,  
19 forced errors) most associated with success on different surfaces are currently unknown.  
20 With three weeks typically separating Roland Garros and Wimbledon, the transition from  
21 clay to grass courts, whereby players must adapt their game style between surfaces, is  
22 crucial to understand. Using the recently validated PWOL method, we analysed 984  
23 singles matches across the 2016 and 2017 Roland Garros and Wimbledon tournaments, to  
24 identify the most important performance characteristics in clay and grass court tennis.  
25 Results revealed that *points won of 0-4 shot rally length, first serve points won* and  
26 *baseline points won* were most strongly associated with success for both sexes; serve-  
27 related performance characteristics (*aces, double faults* and *average first serve speed*) were  
28 among the least associated with success. Furthermore, winning short points (points of 0-4  
29 shots) was more closely associated with success than winning medium-length (5-8 shots)  
30 and long points (9+ shots). To be representative of match-play, findings suggest that  
31 players should afford sufficient practise time to short rallies and point-ending strategies  
32 during the clay and grass court seasons, rather than over-emphasising long rallies.

33 **Keywords:** Elite tennis strategy; court surface; match statistics; winning performance;  
34 tennis coaching

35

36

## 37 **Introduction**

38 Grand Slams are regarded as the most prestigious tennis events of the annual calendar  
39 (International Tennis Federation, 2019). As of 2019, the four Grand Slams are each  
40 contested on a different outdoor court surface; the Australian Open on Plexicushion  
41 Prestige hard courts, Roland Garros on clay courts, Wimbledon on grass courts and the US  
42 Open on DecoTurf hard courts (International Tennis Federation, 2019). Court surfaces are  
43 characterised by two main properties: their coefficient of restitution and their coefficient of  
44 friction (Fernandez-Fernandez, Sanz-Rivas, & Mendez-Villanueva, 2009), and it is these  
45 two key environmental constraints that help shape match-play on different surfaces. For  
46 example, investigations of match-play have demonstrated that more points are contested at  
47 the net on grass courts than hard and clay court surfaces, and that rally lengths are longest  
48 on clay courts (Brown & O'Donoghue, 2008; O'Donoghue & Ingram, 2001). Additionally,  
49 the serve has been shown to be most dominant on grass and least dominant on clay, with  
50 more points won as a direct result of the serve (i.e. either an ace or an unreturned serve) on  
51 grass than on any other surface (Brown & O'Donoghue, 2008; Sogut, 2019).

52 Elite tennis players are required to adapt to different court surfaces during the year,  
53 while attempting to maintain optimal performance levels. Therefore, understanding what  
54 influences success on different surfaces would guide coaches to better prepare their players  
55 for competition (Over & O'Donoghue, 2008) and help to ensure smooth, efficient  
56 transitions between surfaces. While several studies have compared the performance  
57 characteristics of match-play on different court surfaces (e.g. Cui, Gomez, Goncalves, &  
58 Sampaio, 2018, O'Donoghue & Ingram, 2001; Unierzyski & Wieczorek, 2004), few have  
59 attempted to identify which performance characteristics are important and/or most  
60 associated with success. In this context, O'Donoghue (2002), reported that the number of

61 break points won best distinguished between winning and losing players during match-play  
62 on hard courts at the Australian Open. Sogut (2019) recently examined associations  
63 between match-play characteristics and men's world ranking on three different court  
64 surfaces. The percentage of total serve points won, first serve points won and break points  
65 saved were most positively correlated with world ranking on hard, clay and grass courts,  
66 respectively, while the percentage of first serve points won was significantly correlated  
67 with world ranking on all three court surfaces. Reid, McMurtrie and Crespo (2010),  
68 reported that the percentage of second serve (and second serve-return) points won were  
69 most strongly associated with world ranking (i.e. success) in men's tennis. However, Reid,  
70 McMurtrie and Crespo (2010) incorporated data from multiple tournaments, played on a  
71 variety of surfaces over a 12-month period. Although it is well-documented that court  
72 surface influences match-play (Takahashi et al., 2009; Sogut, 2019; Vaverka, Nykodym,  
73 Hendl, Zhanel & Zahradnik, 2018), effects of court surface were not examined by Reid,  
74 McMurtrie and Crespo (2010), which may contribute to the discrepancy between their  
75 results and those reported by O'Donoghue (2002) and Sogut (2019). Sogut (2019), Reid,  
76 McMurtrie and Crespo (2010) and O'Donoghue (2002) further differed in their  
77 methodological approaches, in terms of the performance characteristics selected for  
78 inclusion and their respective operational definitions. Consequently, it is currently unclear  
79 within the literature which performance characteristics are important in terms of winning  
80 for elite tennis players. This issue is apparent for both sexes, but particularly for female  
81 players, as Reid, McMurtrie and Crespo (2010) and Sogut (2019) focused on men's tennis.

82 Previous studies have demonstrated that the differences in match-play  
83 characteristics (e.g. rally length, percentage of first serve points won, number of net-points  
84 played), between Roland Garros and Wimbledon are greater than between all other pairs of  
85 Grand Slams (Brown & O'Donoghue, 2008; Cui et al., 2018; Takahashi et al., 2006).

86 Furthermore, with only 3 weeks typically separating Roland Garros and Wimbledon,  
87 players must adapt their training strategies and attempt to reach optimal performance levels  
88 in a short time frame, so the surface transition from clay to grass is arguably the most  
89 important to understand. Despite this, we do not currently know which match-play  
90 characteristics are important in terms of winning on these two surfaces. Establishing this  
91 would enable more informed training for players during this critical surface-change period.  
92 It would also support the periodisation of training according to court surface, whereby sub-  
93 seasons (e.g. the clay court season, the grass court season) are characterised by surface-  
94 specific training methods (Over & O'Donoghue, 2008; Reid, Morgan & Whiteside, 2016).  
95 For example, if winning baseline rallies is most strongly associated with success on clay  
96 courts, this should be reflected in training sessions, with groundstrokes afforded more  
97 practice time than net-play during the clay court season. Therefore, the aim of this study  
98 was to identify important match-play characteristics on clay and grass court surfaces, for  
99 male and female elite tennis players.

## 100 **Method**

### 101 *Matches*

102 With institutional ethics approval, performance characteristics for the 2016 and 2017  
103 Roland Garros (men n=244 and women n=250) and Wimbledon (men n=241 and women  
104 n=249) singles matches were obtained from the Roland Garros (2017) website and the  
105 Wimbledon Information System (IBM, 2019). Permission to use the Roland Garros data  
106 was granted by the Fédération Française de Tennis; access to the Wimbledon data was  
107 provided by IBM, with permission granted by The All England Lawn Tennis Club. Data  
108 from incomplete matches (i.e. those involving retirements, walkovers or defaults) were

109 excluded from the study; 23 men's matches and 9 women's matches were excluded  
110 accordingly.

### 111 *Performance characteristics*

112 The following commonly used performance characteristics were obtained for  
113 winning and losing players in each match: number of aces, number of double faults,  
114 number of first serves in, average (i.e. mean) first serve speed, number of first serve points  
115 won, number of second serve points won, number of first serve-return points won, number  
116 of second serve-return points won, number of baseline points won, number of net points  
117 won, number of break points won, number of winners, number of forced errors, number of  
118 unforced errors, and number of points won of 0-4, 5-8 and 9+ shot rally length,  
119 respectively.

### 120 *Reliability Testing*

121 The organisation committee for each Grand Slam is responsible for recruiting and  
122 training their own data entry teams; therefore, as different data entry teams collected data  
123 at each event, the reliability of the data collected at each Grand Slam had to be evaluated  
124 separately. To enable inter-rater reliability testing between the researchers and the data  
125 entry teams at each event, video recordings of eight matches (two men's matches and two  
126 women's matches from each Grand Slam) were observed and coded independently by the  
127 lead researcher, using a NacSport (NacSport Elite, Las Palmas de Gran Canaria, Spain)  
128 custom-notational analysis system. Cohen's kappa coefficient was calculated, based on  
129 analysis of over 200 match-play points per Grand Slam (comparing the lead researcher's  
130 results with those recorded by the Grand Slams' respective data collection teams). Cohen's  
131 kappa coefficient was  $k = 0.97$  for Roland Garros data and  $k = 0.99$  for Wimbledon data,  
132 identified as excellent (Fleiss, 1981).

133 ***Data Processing***

134 Data were normalised using the equations in Table 1 for each match, then reduced  
135 to mean ( $\pm sd$ ) for male and female winning and losing players, respectively.

136 [Table 1 near here]

137 ***Data analysis***

138 In each match, the winning player's performance was compared to that of the  
139 losing player (i.e. their opponent) for each performance characteristic, to identify which  
140 player 'outscored' the other. Then, the number of matches in which the winning player  
141 outscored the losing player was tallied for each performance characteristic. Next, the  
142 *Percentage of matches in which the Winner Outscored the Loser* (PWOL; Fitzpatrick,  
143 Stone, Choppin & Kelley, 2019) was calculated, by dividing the number of matches in  
144 which the winning player outscored the losing player for each performance characteristic  
145 by the total number of matches in the respective sample. This provided PWOLs for each  
146 performance characteristic for men and women at each Grand Slam.

147 The PWOL of each performance characteristic was interpreted to indicate their  
148 importance in terms of winning. PWOL analysis produces a result between 0% and 100%  
149 for each performance characteristic. A PWOL of 50% for a particular performance  
150 characteristic means that players who outscored their opponent on this characteristic won  
151 the match in 50% of cases; this equates to no association with success. As the PWOL  
152 increases towards 100%, this indicates a stronger positive association with success (a  
153 stronger association with winning); as the PWOL decreases towards 0%, this indicates a  
154 stronger negative association with success (i.e. a stronger association with losing)  
155 (Fitzpatrick et al., 2019). Accordingly, performance characteristics with either a high



156 PWOL or a low PWOL are considered important, whereas those with a PWOL close to  
157 50% (i.e. between 40% and 60%) are considered less important (Fitzpatrick et al., 2019).  
158 For example, if the winning player hit more aces than the losing player in 150 out of 200  
159 matches at Roland Garros, the PWOL for *aces* on clay would be 75.0%.

160 The PWOL method was developed as a more user-friendly alternative (to point-  
161 biserial correlations and *t* tests) for coaches, to facilitate their understanding of match-play  
162 data analysis; for a detailed validation against Student's *t*-tests and point biserial  
163 correlation methods, see Fitzpatrick et al., 2019. It is important to note that statistical  
164 significance can be calculated for PWOL values, using a binomial distribution with  
165 parameters *n* and *p*, with *n* being the sample size and *p* being the probability of the winning  
166 player outscoring the losing player in a single match.

167 To aid interpretation of results, the mean percentage of points played (per match) within  
168 each rally length category was also calculated for both sexes on clay and grass. Mann-  
169 Whitney *U*-tests were used to identify court surface differences in the mean percentage of  
170 points played within each rally length category for men and women, respectively.

## 171 **Results**

172 Table 2 displays the mean values for winning and losing male players at Roland Garros  
173 and Wimbledon, as well as the PWOL for each associated performance characteristic. The  
174 shaded areas illustrate the characteristics with the highest (top four) and lowest (bottom  
175 two) PWOLs.

176 [Table 2 near here]

177 Table 2 shows that for male players on clay and grass, the four performance  
178 characteristics with the highest PWOLs were *points won of 0-4 shot rally length, first serve*

179 *points won, baseline points won and second serve points won. Forced errors and unforced*  
180 *errors demonstrated the lowest PWOLs on both surfaces. Aces, double faults, successful*  
181 *first serves and average first serve speed* exhibited PWOLs between 44% and 59% at  
182 Roland Garros, and between 33% and 68% at Wimbledon.

183 Table 3 displays the mean values for winning and losing female players at Roland  
184 Garros and Wimbledon, and PWOLs for the associated performance characteristics. The  
185 shaded areas illustrate the characteristics with the highest (top four) and lowest (bottom  
186 two) PWOLs.

187 [Table 3 near here]

188 Table 3 shows that for female players, *points won of 0-4 shot rally length, baseline*  
189 *points won, first serve points won and second serve points won* had the highest PWOLs on  
190 clay and grass. *Forced errors and unforced errors* exhibited the lowest PWOLs on both  
191 surfaces. The serving characteristics *Aces, double faults, successful first serves and*  
192 *average first serve speed*) all exhibited PWOLs between 46% and 58% at Roland Garros,  
193 and of these serving characteristics, only *double faults* demonstrated a PWOL outside of  
194 this range (35%) at Wimbledon.

195 Table 4 displays the mean percentage of points (per match) played within each rally  
196 length category for men and women on clay and grass courts.

197 [Table 4 near here]

198 Table 4 shows that, for men, the mean percentage of points of 0-4 shot rally length  
199 was 3.1% higher at Wimbledon than Roland Garros; accordingly, the mean percentage of  
200 points of 9+ shot rally length was 3.0% lower at Wimbledon. For women, the mean

201 percentage of points of 9+ shot rally length was 1.5% lower at Wimbledon than Roland  
202 Garros.

### 203 **Discussion**

204 The aim of this study was to identify important match-play characteristics on clay and  
205 grass court surfaces, for both sexes. Analysis showed that the same performance  
206 characteristics exhibited the highest and lowest PWOLs, respectively, on both court  
207 surfaces. *Points won of 0-4 shot rally length, first serve points won, baseline points won*  
208 *and second serve points won* exhibited the highest PWOLs (i.e. were most closely  
209 associated with success) for both men and women, at Roland Garros and Wimbledon;  
210 hence, these four performance characteristics are important in terms of winning matches on  
211 clay and grass courts. *Forced errors* and *unforced errors* exhibited the lowest PWOLs for  
212 both sexes, demonstrating that these are also important as they were associated with losing  
213 matches on both surfaces. Often demonstrating PWOLs between 40% and 60%, serve-  
214 related performance characteristics are considered less important, however several serve-  
215 related characteristics were more important on grass than on clay, particularly for male  
216 players. While previous research has suggested that match-play characteristics differ  
217 depending on court surface, results here show that these differences do not necessarily  
218 translate to differences in the *importance* of each performance characteristic.

### 219 ***Performance characteristics associated with winning***

220 For both sexes, *points won of 0-4 shot rally length, first serve points won, baseline*  
221 *points won* and *second serve points won* were most closely associated with winning on clay  
222 and grass courts. However, approximately 60% of points in elite tennis are ‘first serve  
223 points’ and 40% of points are ‘second serve points’ (Brain Game Tennis, 2014), so it is  
224 understandable that both *first serve points won* and *second serve points won* are important.

225 It is also well documented that baseline play has dominated the game since the turn of the  
226 century, in contrast to the 1980s and 1990s, when net play was more prevalent (Crespo &  
227 Reid, 2007). For this reason, the importance of *baseline points won* is understandable.  
228 Additionally, all four of these performance characteristics pertain to ‘points won’, so it  
229 follows that they are likely to be somewhat associated with success.

230 Despite each pertaining to ‘points won’, of the three rally length performance  
231 characteristics, *points won of 0-4 shot rally length* was considerably more important than  
232 *points won of 5-8 shot rally length* and *points won of 9+ shot rally length*, irrespective of  
233 surface and sex. Grass courts have often been shown to exhibit the shortest rally lengths  
234 compared to other court surfaces (Brown & O’Donoghue, 2008; O’Donoghue & Ingram,  
235 2001), so high PWOLs might be expected for *points won of 0-4 shot rally length* on grass  
236 courts. However, the importance of winning short rallies on clay was not expected, as rally  
237 lengths and durations have consistently been shown to be longest on clay courts (Martin et  
238 al., 2011; O’Donoghue & Ingram, 2001; Takahashi et al., 2006; although since the mid-  
239 2000s, the differences between rally lengths on different surfaces have reduced somewhat  
240 (Brown & O’Donoghue, 2008; Lane, Sherratt, Hu, & Harland, 2017; Martin & Prioux,  
241 2016). In this analysis, male players who won more short rallies (points of 0-4 shot rally  
242 length) than their opponent won the match in 89% of cases at Roland Garros. Despite clay  
243 courts typically being associated with long rallies, the data presented in Table 4 reveals an  
244 underlying prevalence of short rallies on both surfaces. While perhaps unexpected, this  
245 helps explain why short points are so important on clay, as well as on grass, as they  
246 comprised a large proportion of total points played on both surfaces. In turn, this also  
247 indicates that the outcome of a large proportion of points may be determined by the quality  
248 of the serve and/or the serve-return. Future work to identify how points of 0-4 shot rally  
249 length are won would be beneficial and provide further insight here, particularly as this

250 performance characteristic was the most important in 3 of the 4 instances. In a coaching  
251 context, the importance of short points and their prevalence on the two surfaces are  
252 relevant. Pinder, Davids, Renshaw and Araujo (2011) explained that to optimise learning,  
253 athletes' training sessions should be representative of the performance environment (i.e.  
254 match-play). Therefore, results here suggest that elite players' practice sessions should not  
255 have an over-emphasis on long rallies and consistency during the clay and grass court  
256 seasons, but instead afford sufficient time to practising serves, serve-returns and point-  
257 ending strategies, in order to be representative of match-play.

### 258 ***Performance characteristics associated with losing***

259 For both sexes, *forced errors and unforced errors* were the performance  
260 characteristics most closely associated with losing on clay and grass. For male players,  
261 *forced errors* exhibited a lower PWOL (closer to 0%) than *unforced errors* at Roland  
262 Garros and Wimbledon, suggesting that forced errors are more important than unforced  
263 errors for men on both surfaces. For female players on grass courts, *unforced errors* were  
264 more important (with a PWOL closer to 0%) than *forced errors*. The higher unforced error  
265 rate (compared to forced errors) exhibited by women here may be related to the tendency  
266 for female players to adopt a one-dimensional 'power' gamestyle (Rutherford, 2017),  
267 hitting the ball earlier and flatter in an attempt to apply pressure and out-hit their opponents  
268 from the baseline (Antoun, 2007); a tactic that presents an inherent risk of 'over-hitting'  
269 (i.e. committing an unforced error). In contrast, male players, who are naturally able to hit  
270 the ball harder and typically have more tactical variety than women (Antoun, 2007), tend  
271 not to adopt the risky power-hitting strategy. Instead, they attempt to exploit free space on  
272 the court, using different spins and ball speeds to put their opponent under pressure  
273 (Antoun, 2007), in turn inducing more forced errors. In this context, it is important for

274 coaches to be aware of and understand the differences in tennis strategies between men and  
275 women, so any expectations and goals set are realistic and sex-specific.

276 ***Performance characteristics least associated with match outcome***

277 For male players, four serve-related performance characteristics (*aces, successful*  
278 *first serves, double faults* and *average first serve speed*) exhibited PWOLs between 44%  
279 and 59% on clay (indicating that serving is not important in terms of winning), but outside  
280 of this range on grass (*double faults* - 33%, *average first serve speed* - 60%, *successful first*  
281 *serves* - 61%, *aces* - 68%). This suggests men's serving is more important on grass than on  
282 clay. This also corresponds with the differences in rally lengths between the two events  
283 (see Table 4); the fact that more short rallies were played by men at Wimbledon than at  
284 Roland Garros may be a reflection of the greater importance of the serve on grass than on  
285 clay. On grass courts, the lower coefficients of friction and restitution (compared to clay)  
286 mean that, after a serve lands, the ball loses less horizontal velocity and bounces lower,  
287 respectively (Miller, 2006). Accordingly, the ball approaches the returning player faster,  
288 affording them less time to prepare for and perform the serve-return (Filipic, Caks, &  
289 Filipic, 2011). The returner is therefore less likely to successfully return the serve into  
290 play, so the server may win a higher proportion of points directly from their serve. If  
291 players recognise this, intuitively or otherwise, it could also explain the faster serve speeds  
292 at Wimbledon, where a fast serve may be more likely to be rewarded with a 'cheap' point  
293 than on the slower, higher bouncing clay courts at Roland Garros (Giampaolo & Levey,  
294 2018).

295 For female players, *aces, successful first serves* and *average first serve speed*  
296 exhibited PWOLs between 46% and 58% on both surfaces, with *double faults* exhibiting a  
297 PWOL outside of that range (35%) only at Wimbledon. So, it appears that serving is not

298 important in terms of winning matches on clay or grass for women. This supports previous  
299 observations that the serve is a more effective weapon for male players than female players  
300 (Furlong, 1995), and that tactically, women tend to use their serves as a means of starting a  
301 point, rather than gaining an advantage or winning points directly (Filipic et al., 2011).  
302 With female players typically producing lower serve speeds than male players, returners  
303 are afforded more time to plan and perform the serve-return, so points are less likely to be  
304 won directly from the serve.

305 In a practical context, these serve-related results indicate that enhancing a player's  
306 serve performance should not be a priority for coaches during the clay court season, and  
307 that only male players should afford serving additional practice time during the grass court  
308 season. Interestingly, though, *first serve points won* and *second serve points won* exhibited  
309 high PWOLs (73%+) irrespective of court surface and sex. So, perhaps the serve allows  
310 players to gain somewhat of a 'lasting' advantage in the rally, even though the more  
311 'immediate' serving characteristics (*aces*, *double faults*, *first serve percentage* and *average*  
312 *first serve speed*) do not appear to be of great importance, particularly on clay. If this is the  
313 case, it may be prudent for coaches to focus on integrating the serve into a player's holistic  
314 match strategy rather than aiming to win points directly from their serve.

## 315 **Conclusion**

316 *Points won of 0-4 shot rally length*, *first serve points won*, *baseline points won* and  
317 *second serve points won*) were most closely associated with winning for both sexes on clay  
318 and grass court surfaces. Accordingly, short points and point-ending strategies should be a  
319 focus for players during grass and clay court season training. *Forced errors* and *unforced*  
320 *errors* were most closely associated with losing on both surfaces, and serve-related  
321 characteristics were only somewhat important for male players on grass. These results

322 suggest that training need not drastically differ for either sex when transitioning from clay  
323 courts to grass courts, but that male players may wish to afford extra practice time to  
324 serving during the grass court season. Accordingly, players may wish to prioritise getting  
325 used to the surface (e.g. modifying their movement patterns and adapting to the different  
326 ball-court surface interactions), rather than specific areas of their game, such as approach  
327 shots or net-play, when transitioning from clay to grass before Wimbledon. Future work  
328 analysing short rallies in more detail would enhance our understanding, revealing how  
329 such points are won by elite male and female players.

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### 334 *Declaration of Interest*

335 The authors report no conflict of interest.

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Table 1. Normalised performance characteristic calculations, derived from O'Donoghue and Ingram (2001) and O'Donoghue (2005).

Performance characteristic	Equation
Aces	(Number of aces/number of serves performed) x 100
Double faults	(Number of double faults/number of points served) x 100
Successful first serves	(Number of first serves in/number of first serves attempted) x 100
First serve points won	(Number of first serve points won/number of first serve points played) x 100
First serve-return points won	(Number of first serve-return points won/number of first serve-return points played) x 100
Second serve points won	(Number of second serve points won/number of second serve points played) x 100
Second serve-return points won	(Number of second serve-return points won/number of second serve-return points played) x 100
Break points won	(Number of break points won as returner/number of break points played as returner) x 100
Net points won	(Number of net points won/number of net points played) x 100
Baseline points won	(Number of baseline points won/number of baseline points played) x 100
Winners	(Number of winners/number of rally points played) x 100
Forced errors	(Number of forced errors/number of rally points played) x 100
Unforced errors	(Number of unforced errors/number of rally points played) x 100
Points won of 0-4 shot rally length	(Number of points won of 0-4 shot rally length/number of points played of 0-4 shot rally length) x 100
Points won of 5-8 shot rally length	(Number of points won of 5-8 shot rally length/number of points played of 5-8 shot rally length) x 100
Points won of 9+ shot rally length	(Number of points won of 9+ shot rally length/number of points played of 9+ shot rally length) x 100

Table 2. Mean ( $\pm$  *sd*) for each performance characteristic for winning and losing male players at Roland Garros and Wimbledon, and associated PWOLs.

Performance characteristic	Roland Garros			Wimbledon		
	Winning players	Losing players	PWOL	Winning players	Losing players	PWOL
Number of points won of 0-4 shot rally length	83.1 $\pm$ 23.6	70.2 $\pm$ 25.8	89%	81.8 $\pm$ 25.4	67.9 $\pm$ 28.5	92%
Number of first serve points won	48.9 $\pm$ 14.7	44.3 $\pm$ 15.6	85%	56.4 $\pm$ 17.0	50.8 $\pm$ 18.3	85%
Number of baseline points won	69.6 $\pm$ 20.0	56.7 $\pm$ 22.3	82%	55.2 $\pm$ 18.0	45.3 $\pm$ 18.7	79%
Number of second serve points won	22.8 $\pm$ 7.4	20.6 $\pm$ 8.2	77%	22.5 $\pm$ 7.5	21.7 $\pm$ 8.0	73%
Number of break points won	5.5 $\pm$ 2.0	2.5 $\pm$ 2.1	71%	4.5 $\pm$ 1.7	1.7 $\pm$ 1.6	68%
Number of points won of 9+ shot rally length	12.3 $\pm$ 7.6	10.3 $\pm$ 7.3	66%	8.7 $\pm$ 6.1	7.0 $\pm$ 5.8	61%
Number of points won of 5-8 shot rally length	23.2 $\pm$ 8.2	20.1 $\pm$ 8.9	65%	22.4 $\pm$ 8.4	18.9 $\pm$ 8.2	69%
Number of winners	39.0 $\pm$ 13.7	33.6 $\pm$ 14.5	64%	29.2 $\pm$ 10.6	25.0 $\pm$ 11.1	61%
Number of net points won	14.1 $\pm$ 8.0	13.8 $\pm$ 8.4	62%	21.2 $\pm$ 9.8	19.8 $\pm$ 11.0	57%
Number of aces	7.5 $\pm$ 6.4	5.7 $\pm$ 4.7	59%	12.5 $\pm$ 8.5	9.1 $\pm$ 7.9	68%
Number of successful first serves	66.2 $\pm$ 21.3	67.6 $\pm$ 21.3	56%	72.0 $\pm$ 22.3	73.0 $\pm$ 21.7	61%
Average first serve speed (km/h)	181.8 $\pm$ 9.7	180.9 $\pm$ 10.7	51%	188.6 $\pm$ 8.8	185.2 $\pm$ 10.2	60%
Number of double faults	3.4 $\pm$ 2.5	3.8 $\pm$ 2.7	44%	3.4 $\pm$ 2.5	4.5 $\pm$ 2.6	33%
Number of unforced errors	30.9 $\pm$ 14.9	37.4 $\pm$ 14.8	33%	21.9 $\pm$ 10.5	25.7 $\pm$ 10.6	34%
Number of forced errors	36.2 $\pm$ 13.2	42.2 $\pm$ 12.8	22%	44.5 $\pm$ 14.8	50.0 $\pm$ 13.4	27%

Table 3. Mean ( $\pm$  *sd*) for each performance characteristic for winning and losing female players at Roland Garros and Wimbledon, and associated PWOLs.

Performance characteristic	Roland Garros			Wimbledon		
	Winning players	Losing players	PWOL	Winning players	Losing players	PWOL
Number of points won of 0-4 shot rally length	52.8 $\pm$ 15.8	43.7 $\pm$ 17.3	85%	48.4 $\pm$ 14.2	39.0 $\pm$ 16.3	87%
Number of baseline points won	49.8 $\pm$ 14.4	40.4 $\pm$ 16.0	84%	44.0 $\pm$ 13.2	35.6 $\pm$ 15.7	90%
Number of first serve points won	30.5 $\pm$ 9.3	25.8 $\pm$ 10.1	83%	32.0 $\pm$ 9.9	28.0 $\pm$ 11.3	84%
Number of second serve points won	12.5 $\pm$ 4.9	11.0 $\pm$ 5.4	76%	13.3 $\pm$ 5.0	11.5 $\pm$ 5.3	79%
Number of winners	25.3 $\pm$ 9.5	20.6 $\pm$ 11.3	68%	20.3 $\pm$ 9.0	16.6 $\pm$ 8.9	64%
Number of points won of 5-8 shot rally length	17.1 $\pm$ 7.2	14.8 $\pm$ 7.6	68%	17.9 $\pm$ 7.2	14.5 $\pm$ 7.1	72%
Number of break points won	5.1 $\pm$ 1.7	2.8 $\pm$ 1.9	66%	4.5 $\pm$ 1.4	2.1 $\pm$ 1.7	63%
Number of successful first serves	46.3 $\pm$ 15.6	45.4 $\pm$ 14.6	58%	45.5 $\pm$ 16.3	45.8 $\pm$ 15.9	57%
Number of aces	2.5 $\pm$ 2.4	1.8 $\pm$ 2.2	57%	3.4 $\pm$ 3.0	2.5 $\pm$ 2.6	57%
Number of points won of 9+ shot rally length	8.7 $\pm$ 5.7	7.6 $\pm$ 5.6	56%	7.4 $\pm$ 5.5	6.2 $\pm$ 4.9	58%
Number of net points won	8.2 $\pm$ 5.0	7.8 $\pm$ 5.9	54%	10.9 $\pm$ 6.8	9.0 $\pm$ 5.6	66%
Average first serve speed (km/h)	155.3 $\pm$ 10.5	154.7 $\pm$ 9.9	52%	159.4 $\pm$ 9.5	158.4 $\pm$ 8.4	51%
Number of double faults	2.8 $\pm$ 2.4	3.1 $\pm$ 2.3	46%	2.8 $\pm$ 2.2	3.6 $\pm$ 2.3	35%
Number of forced errors	21.9 $\pm$ 9.3	25.4 $\pm$ 9.0	34%	25.5 $\pm$ 10.3	30.7 $\pm$ 10.0	35%
Number of unforced errors	22.8 $\pm$ 10.2	27.7 $\pm$ 11.0	34%	17.0 $\pm$ 9.3	20.5 $\pm$ 9.7	21%

Table 4. Mean percentage of points played within each rally length category for men and women at Roland Garros and Wimbledon.

Percentage of points played	Men		Women	
	Roland Garros	Wimbledon	Roland Garros	Wimbledon
0-4 shot rally length	69.0%	72.1% <sup>*</sup>	65.1%	65.9%
5-8 shot rally length	20.2%	20.1%	23.4%	24.1%
9+ shot rally length	10.8%	7.8% <sup>*</sup>	11.5%	10.0% <sup>+</sup>

<sup>\*</sup> Different to men at Roland Garros ( $p < 0.001$ ). <sup>+</sup> Different to women at Roland Garros ( $p < 0.05$ ).