## Instructions for Authors

### 1. Scope

The International Journal of Performance Analysis in Sport is published on behalf of the Centre for Performance Analysis, Cardiff School of Sport at Cardiff Metropolitan University and in association with the International Society of Performance Analysis in Sport. The emphasis is on the analysis of actual performance in sport and exercise. Studies using observational methods, biomechanical analysis, self-report emanating from actual sports performance, qualitative observation and measurements such as heart rate response during actual sports performance are all within the scope of the journal. Laboratory studies of key techniques within sports are also of interest where such techniques are clearly important and cannot be analysed in detail during actual competition. Such techniques include tennis serves and golf swings. There may be other contributions that do not analyse sports performance at all that are within the scope of the journal. For example, interview studies or meta-analyses may lead to theoretical contributions explaining the nature of sports performance, tactics used and factors influencing performance. Review articles relevant to sports performance are also welcome. Other topics covered include technologies such as design of analysis systems, sports equipment, research into training, and modelling and predicting performance. Contributors wishing to clarify whether papers they are writing are within the scope of the journal are welcome to contact the general editor.

The volume of papers published by the journal has increased from 40 in 2008 to 68 in 2013 and as a consequence the quality of accepted papers has also increased. Authors should use the most recent issues of the journal to understand the required quality. Authors should ask themselves the following questions when preparing a paper.

(a) Does the paper report on a substantive research exercise? If the data could be gathered and analysed over a single weekend, the authors should consider submitting the work for poster presentation at a conference.
(b) Is the research sufficiently original? Will the paper have impact? Does the paper make a contribution to our knowledge of something important about sports performance?
(c) Does the research warrant the number of authors listed on the paper? This has become a problem with a lot of recent submissions where the nature and volume of the work certainly does not warrant the number of authors included. In cases like this, the paper has not been sent for review and has been rejected by the editor.
(d) Is the analysis sufficiently rigorous? Authors should consider the reliability of methods used, the units of analysis used, the choice of independent and dependent variables and the assumptions of any statistical tests used. In saying this, there is nothing wrong with original descriptive research and authors should avoid complex predictive modelling designs where these are not appropriate.
(e) Does the paper fit within the scope of the journal? Sports performance analysis does involve a more expanded array of methods and types of study these days. However, there have been papers submitted to the journal that are clearly not performance analysis papers. Some of these papers are of a very high quality in all other respects, but they are simply not within the scope of the journal.

## 2. Submission

Authors must submit an original article in electronic form, (preferably by e-mail) in Microsoft Word, to the General Editor (podonoghue@cardiffmet.ac.uk). Papers submitted to the Journal will be refereed blind by acknowledged experts in the subject. The General Editor has the final decision on publication. No word limits are specified for papers, but discursive treatments of the subject matter are discouraged. The Journal does not normally publish letters to the editor.

Due to the volume of papers submitted, we now require authors to provide the names of three potential expert independent reviewers for their paper.

## 3. Originality

All material submitted for publication in the journal must be accompanied by a statement by the lead author, with the authority of all of the authors, that: the material submitted is original and unpublished, and is not under consideration for publication elsewhere and that the material will not be submitted for publication elsewhere while it is under consideration by the journal.

## 4. Format

Papers consist of a title page, blind title page and the main text of the paper. Figures and tables should be included in the text rather than following the text. Typical sections of the text are Introduction, Methods, Results, Discussion, Conclusions, any acknowledgements, References and author correspondence details. However, it is acceptable to have a conclusions paragraph at the end of the discussion. Further variation is possible for review articles or where papers report on a series of studies which are best reported in a study by study order.

Page Layout
Pages must be A4 using margins of 3cm at the top, bottom, left and right. Portrait orientation is used except where landscaped orientation clearly assists the presentation of tables and / or figures. Paragraph text should be single spaced.

*Title Page*
The title page should contain the title (Times Roman, size 18, bold), author names using first names, other initials and surnames and affiliations of authors, the abstract and key words. All text other than the abstract should use Times Roman size 12 font. The abstract should be bold and in italics not exceeding 200 words. It should be inserted in the article after the authors' affiliations and indented by 1 cm at the left and right. The abstract should not contain figures or tables.

*Blind Title Page*
This should include all of the information on the title page except the author names and affiliations. Where acknowledgements or information in the methods about ethical clearance may compromise the blind reviewing process, the General Editor will temporarily remove this information while the paper is being reviewed.

*Headings*
Headings and subheadings should all be in Times Roman font, bold and size 12. Headings should be numbered 1., 2., 3., etc with any subheadings being 1.1., 1.2., for example.

*Tables*
Tables should normally only include horizontal lines to mark the top and bottom and separate column headings from the main body of tables. Tables must be created in word to facilitate any necessary editing by the journal. There are occasions, where correlation tables, for example, require vertical lines and this is acceptable. Table captions should appear above the table.

*Figures*
Illustrations, photographs, screen dumps, charts, plates and any other artwork should be included in the electronic submission. Authors must have permission to use any photographs within the paper and copyrighted material from published sources must not be included as Figures in the paper. Figure headings should be placed below figures.

*Symbols, units and abbreviations*
Symbols, units and abbreviations in papers must conform to the Système International d'Unités (SI Units). Authors are advised to consult the National Physical Laboratory publication (R.J. Bell (ed. ), 1993, SI: The International System of Units. London: HMSO). For all abbreviations other than units, write the word or words to be abbreviated in full on the first mention followed by the abbreviation in parentheses. If at all possible, group these definitions together near the beginning of the article. As indicated earlier, avoid use of nonstandard abbreviations, especially fabricated ones, within the text; words are much easier to read and follow than abbreviations.

*References*
References in the text are cited as follows: Smith (1985) ... or (Brown and Green, 1996) ... or, if there are more than two authors, as Jones *et al*. (1993) ... or (Jones *et al*., 1993). Citations of different publications by the same author(s) in the same year are differentiated as Green (1993a) ... (Brown *et al*., 1995b); the a, b, c, etc. , are normally in order of citation in the text. Multiple citations are listed in ascending chronological order. Multiple publications by the same authors are treated in lists: Smith (1991, 1995), Brown and Green (1992, 1993), Jones *et al*. (1993, 1996a,b); or (Smith, 1991, 1995; Brown and Green, 1992, 1993; Jones *et al*., 1993, 1996a,b). A list of all cited references should be collected at the end of the paper in alphabetical order by, in the first instant, the first author's surname. Where the name of the first author appears more than once, the order is determined by: first, the number of co-authors (zero, one, or more than one); secondly, for one co-author, the first co-author's surname then the year; for two or more co-authors, year then order as dictated by the use of 1990a,b,c (for example) in the citations. The following is an example of how references would be ordered in the reference list: Brown (1980), Brown (1990), Brown and Jones (1977), Brown and Smith (1973), Brown and Smith (1975), Brown *et al*. (1990a), Brown *et al*. (1990b), Brown *et al*. (1990c). Note that the last three examples would all have been cited as Brown et al. in the text, with the a, b and c relating to the order of citation. The names and initials of all authors should be given in the list of references. The style should follow the examples below:

<u>Journal Papers</u>
Newton, P.K. and Keller, J.B. (2005), The probability of winning at tennis, Theory and Data, **Studies in Applied Mathematics**, 114, 214-269.

<u>Books</u>
Ashe, A. (1981), **Arthur Ashe's Tennis Clinic**. London: Heinemann.

Chapters of Edited Books (including conference proceedings published as books)

Hughes, M. and Clarke, S. (1995), Surface effect on elite tennis strategy. In Reilly, T., Hughes, M. and Lees, A. (Eds.) **Science and Racket Sports** (pp. 272-277). London: E & FN Spon.

Conference abstracts published in journals

O'Donoghue, P.G. (2003), The effect of scoreline on elite tennis strategy: a cluster analysis. **Journal of Sports Sciences**, 21, 284-285.

## 5. Proofs

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## 6. Copyright

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## 7. An example of a published paper

# Break points in Grand Slam men's singles tennis

Peter O'Donoghue

Cardiff School of Sport, Cardiff Metropolitan University, Cyncoed Campus, Cardiff, Wales, CF23 6XD, UK.

**Abstract**

***The current investigation was composed of two related studies. The aim of the first study was to compare the proportion of break points and non-break points won by players receiving serve in matches of the 2011 US Open men's singles tournament. Match statistics were recorded from the official tournament website for the 92 matches where both players had at least 5 break points. Wilcoxon signed ranks tests revealed that winning players won a significantly greater proportion of break points than non-break points (p = 0.004) while losing players won a similar proportion of break points to non-break points (p = 0.994).***

***The aim of the second study was to compare the proportion of break points and non-break points won by the World's top 4 tennis players. There were 27 to 39 singles matches for each of these players within Grand Slam tournaments between 2008 and 2011 where the players and their opponents had at least 5 break points each. A series of 95% confidence intervals of the mean revealed different scoreline effects for these players. The findings of these two studies challenge the assumption of stationarity used in models of winning games of tennis.***

***Key words:*** performance analysis, stationarity, probability, modelling.

## 1. Introduction

Models of tennis games have been developed based on the assumptions of stationarity and independence of points (Hsi and Burych, 1971; Carter and Crews, 1974; Morris, 1977; Pollard, 1983; Croucher, 1986; Newton and Keller, 2005). Stationarity is the assumption that the probability of winning a tennis point is not influenced by the game score at the beginning of the point. Independence is the assumption that the probability of winning a tennis point is not influenced by the outcome of preceding tennis points. These assumptions are made by the model of winning tennis points shown in equation (1) where p is the probability that the server wins a point and q is the probability that the receiver wins a point (q = 1 – p). This model has been used to determine the importance of different points in tennis games with 30-40 being the most important point where p is 0.6 (Morris, 1977).

$$P(\text{Hold serve}) = p^4(1+4q+10q^2) + 20p^5q^3 / (1-2pq) \qquad (1)$$

Male players won a significantly greater percentage of break-points than other receiving points in Grand Slam singles matches in 2008 and 2009 (Knight and O'Donoghue, 2012 In

Press). Klaassen and Magnus (2001) found that the probability of the receiving player winning a point increases during important points. This challenges the assumption of stationarity and lead to the alternative model shown in equation (2) that distinguished between break points and non-break points (Knight and O'Donoghue, 2012, In Press). In equation (2), the probability of the server winning a point is $p_A$ during non-break points and $p_B$ during a break point, with the probability of the receiving player winning points in these situations being $q_A = 1 - p_A$, and $q_B = 1 - p_B$ respectively.

$$P(\text{Hold}) = p_A^4(1+4q_A+10q_A^2)+p_A^2q_A^3(10p_A^3+p_B^3+3p_Ap_B^2+6p_A^2p_B)/(1-q_A(p_A+p_B)) \quad (2)$$

However, Knight and O'Donoghue's (2012 In Press) study can be criticised on two grounds. Firstly, they included any matches where both players had break points. This meant that some matches were included where a player may have had a single break point. This would give a value for $q_B$ of 0 or 1 depending on whether this single point was won or lost. Such matches were given an equal weighting to matches where both players had many more break points. The second limitation of the study was that average results were reported for each tournament and men's singles Grand Slam singles tennis in general without distinguishing between the performances of winning and losing players within matches. In recent years, four players have dominated the men's singles game; Novak Djokovic, Roger Federer, Rafael Nadal and Andy Murray. It would be interesting to look at the receiving performance of these players.

Therefore, the current paper describes two related studies of receiving performance during Grand Slam men's singles tennis. The purpose of the first study was to compare the receiving performance of winning and losing players within matches of the 2011 US Open men's singles during break points and non-break-points. The purpose of the second study was to compare performance during break-points and non-break points for the World's top 4 male players during all 16 Grand Slam tournaments from the Australian Open in 2008 to the US Open in 2011.

## 2. Study 1: Winning and losing performances at the US Open

### 2.1. Methods

Data for the first study were gathered from the official website of the US Open (www.usopen.org, accessed 13th December 2011). The data were recorded onto a specifically designed data collection form before being entered into Microsoft Excel for processing. The criteria for matches to be included in the study were that the match had to be a completed match where both players had at least 5 break points. There were 92 men's singles matches in the 2011 US Open that satisfied these criteria. The following data for each match were compiled into a spreadsheet.

- The tournament.
- The winning and losing players.
- The number of receiving points played and won by each player.
- The number of break points played won by each player.
- The number of games where each player returned serve. If the total number of non-tiebreak games played in the match was even, an equal number of return games was played by each player. If the total number of games was odd then the player who

served first was determined using the number of service breaks within the first set that had an odd number of games.

The spreadsheet of player performances was programmed to calculate the retrospective probability of each player winning a point when receiving serve ($q$) and the retrospective probability of the opponent winning a point on serve ($p = 1 - q$). The expected number of break points created per receiving game and the probability of breaking the opponent's serve were computed using equations (3) and (4) respectively.

$$E(\text{BREAK POINTS PER GAME}) = q^3(1+4p+10p^2) + 20q^4p^3 / (1-2pq) \quad (3)$$

$$P(\text{BREAK}) = q^4(1+4p+10p^2) + 20q^5p^3 / (1-2pq) \quad (4)$$

The observed number of break points created and number of break points converted were divided by the number of receiving games in each performance to compute the actual number of break points per game and breaks per game. The number of service breaks was divided by the number of break points played to determine a value for $q$ during break points, $q_B$. The break points won and break points played were also subtracted from the number of points won and played respectively when receiving serve to determine a value for $q$ during non-break points, $q_A$.

Mean and SEM values were computed for the observed and expected number of breakpoints as well as the retrospective probabilities of winning receiving points during break points and non-break points. A series of Kolmogorov-Smirnov tests revealed that 5 of the 8 variables (3 out of 4 for the winning players and 2 out of 4 for the losing players) were not normally distributed and therefore pairs of conditions were compared using nonparametric Wilcoxon signed ranks tests. Where the Wilcoxon signed ranks tests produced p values of less than 0.05, statistical significance was concluded for the difference between related samples.

**2.2. Results**

Table 1 shows that there was no significant difference between the expected and observed break points per receiving game for the winning or losing players within matches of the 2011 US Open ($p > 0.05$).

Table 1. Expected and observed break points per receiving game in the 2011 US Open men's singles (mean±SEM).

| **Player** | **Break points played per receiving game** | | **Wilcoxon signed rank test** | |
|---|---|---|---|---|
| | **Expected** | **Observed** | **z** | **p** |
| Winner | 0.75±0.021 | 0.73±0.032 | -1.6 | 0.108 |
| Loser | 0.45±0.016 | 0.47±0.021 | -0.8 | 0.416 |

Figure 1 shows the mean±SEM for the retrospective probability of winning break points and non-break points for the winning and losing players within receiving games of these matches. There was no significant difference between the proportion of break points and non-break points won by losing players ($z = -0.0$, $p = 0.994$). However, winning players won a significantly greater proportion of break points than non-break points ($z = -2.9$, $p = 0.004$).

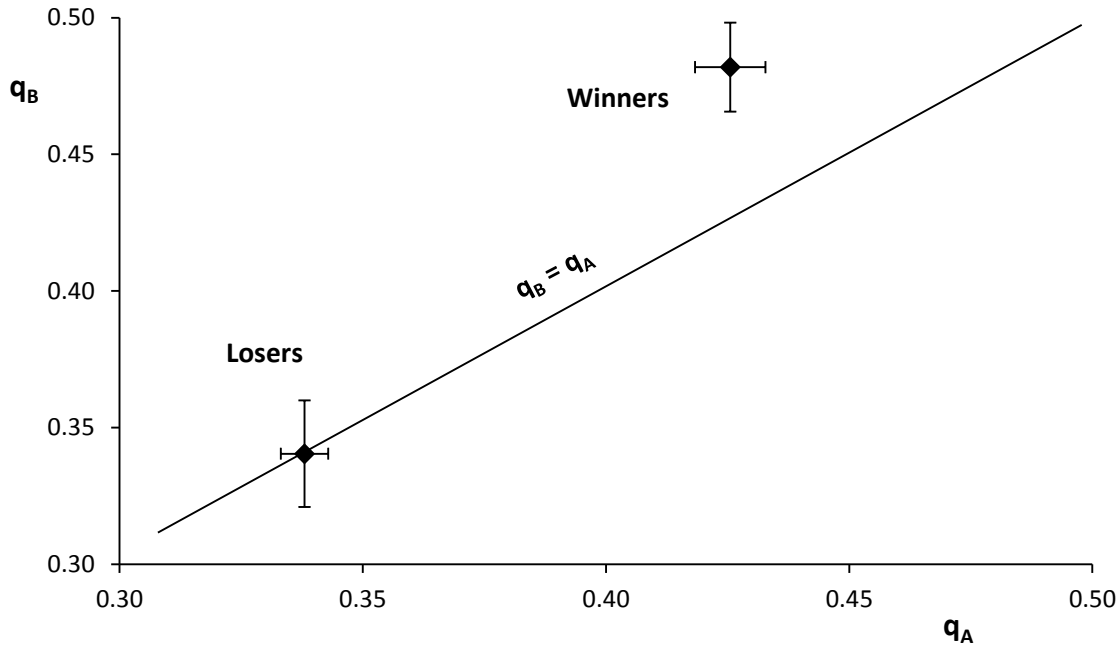


Figure 1. Retrospective probability of winning points during receiving games of the 2011 US Open men's singles during break points ($q_B$) and non-break points ($q_A$). Mean values are plotted and error bars represent SEM values.

## 3. Study 2: The World's Top Four Players

### 3.1. Methods

The criteria for a match to be included in the second study were that the match involved at least one of the World's top four players, was played in a men's singles event of a Grand Slam tournament between 2008 and 2011 inclusive and each player within the match had at least 5 break points. These data were recorded from the official internet sites of the four Grand Slam tournaments (www.ausopen.org accessed 29th December 2008, 2nd February 2009, 15th September 2010, 7th February 2012, www.fropen.org accessed 29th December 2008, 24th July 2009, 15th September 2010, 7th February 2012 www.wimbledon.org accessed29th December 2008, 24th July 2009, 15th September 2010, 7th February 2012, www.usopen.org accessed 29th December 2008, 16th September 2009, 15th September 2010, 13th December 2011). Table 2 shows the volume of data recorded for the second study. The lower volume of data recorded from Wimbledon was due to greater server dominance leading to fewer break points being played at this tournament than at the other tournaments.

Table 2. Matches from each Grand Slam tournaments included in the second study.

| Player | Australian Open | French Open | Wimbledon | US Open | Total |
|---|---|---|---|---|---|
| Djokovic | 9 | 12 | 10 | 8 | 39 |
| Federer | 7 | 8 | 2 | 10 | 27 |
| Murray | 10 | 13 | 4 | 9 | 36 |
| Nadal | 10 | 15 | 3 | 7 | 35 |

The same variables were used for the second study as the first study and a second spreadsheet was programmed to produce the $q_A$ and $q_B$ values for each player performance. The data for

the second study were summarised using the means and 95% confidence intervals for the means for the World's top 4 players.

### 3.2. Results

Figure 2 summarises the results of the second study, showing that only Rafael Nadal won a greater proportion of break points than non-break points (above the $q_B = q_A$ line). There are three results based on 95% confidence intervals for player means. Firstly, Nadal won a significantly greater proportion of break points than the other three. Secondly, Murray won significantly more non-break points than Djokovic. Thirdly, all of the players except Novak Djokovic perform significantly differently to a hypothesised performance where stationarity can be assumed (on the $q_B = q_A$ line).

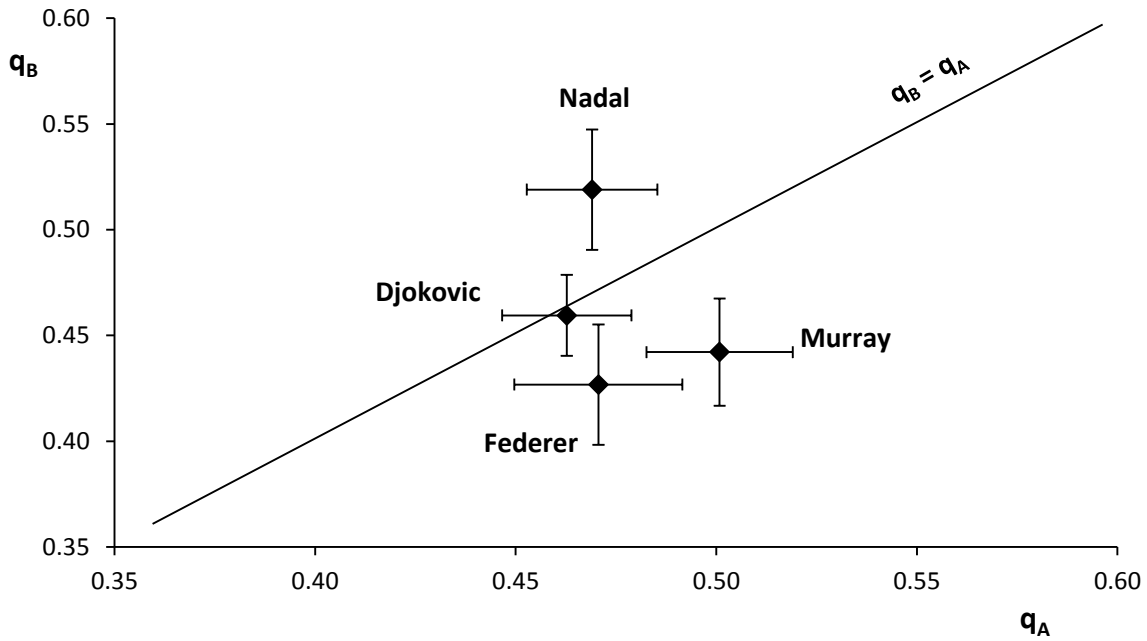


Figure 2. Retrospective probability of the World's top 4 players winning points during receiving games of Grand Slam men's singles tournaments from 2008 to 2011; break points ($q_B$) and non-break points ($q_A$). Mean values are plotted and error bars represent SEM values.

## 4. Discussion

Some results of the first study disagreed with Knight and O'Donoghue (2012 In Press) who found players generated more break points than would be expected given the number of points won when receiving. This may be explained by methodological differences between Knight and O'Donoghue's study and the current investigation. Matches where one or both player had fewer break points were excluded from the current investigation while matches with relatively high numbers of break points were still included. Some players achieving a low number of break points may still be earning more break points than expected given the proportion of points they win when receiving serve. A further issue is that matches where both players earn at least 5 break points may involve higher ranked players than those involved in Knight and O'Donoghue's study. Figure 1 partially agrees with the finding of O'Donoghue (2001) that score-line does not influence the probability of winning a point and

partially agrees the contradicting research by Knight and O'Donoghue that score-line within games does influence the probability of winning a point. The losing players won a similar percentage of break points and non-break points while the winning players won a significantly greater percentage of break points than non-break-points.

Figure 2 illustrates the result of the second study that the receiving performances of the World's top four players are influenced in different ways by score-line. Rafael Nadal converts a greater percentage of break-points than non-break points, Novak Djokovic is unaffected by score-line, while Roger Federer and Andy Murray convert a lower percentage of break points than non-break points. This is explained by individual differences in performers which has been recognised in sports performance for some time (McGarry and Franks, 1994; Grehaigne *et al*., 1996). In particular, there are different types of tennis player with respect to how game score influences strategy (O'Donoghue, 2003). Where a player wins a greater proportion of break points than non-break points, it is possible that the players make less effort on the non-break points than break-points rather than more effort on the break points. It would be most likely that the serving opponent would also make their best effort to win such a critical point. Therefore, this result may be explained by a player such as Nadal not making the same effort in points such as 40-15, 30-0 and 40-0 as he does on other points when receiving serve. Serve return may differ between players and have more impact on some points than others. For example, Ashe (1981) recommended that at a score of 40-0, the server should "try the cannonball". Where a returning player is not as effective as returning such a serve as other players might be, it may lead to lower numbers of points being won against the serve at 40-0 than at other score-lines.

Andy Murray and Roger Federer win a lower proportion of break-points than other points and yet are among the World's top four players. This may be explained by such players breaking serve by generating more break points that higher numbers of service breaks will be achieved even with a lower conversion rate. Consider the match between Andy Murray and Viktor Troicki in the 4$^{th}$ Round of the 2011 French Open. Murray won 9 out of 23 break points (39%) while Troicki won 7 out of 13 break points (54%). Troicki's superior conversion of break points needs to be considered along with the number of break points earned when comparing with Murray's performance in this match.
The differences between the World's top four players challenge the assumption of stationarity used in models of winning tennis games (Morris, 1977; Croucher, 1986). Only Novak Djokovic won a similar proportion of break points as non-break points. However, the models have been shown to be robust to violations of the assumption of independence (Newton and Aslam, 2006). It is, therefore, worth considering the impact of violations of stationarity based on the performances observed for Rafael Nadal ($q_A = 0.9q_B$) and Roger Federer ($q_B = 0.9q_A$). Figure 3 shows that the probability of the serving player winning the game is robust then playing against opponents with such violations of stationarity.

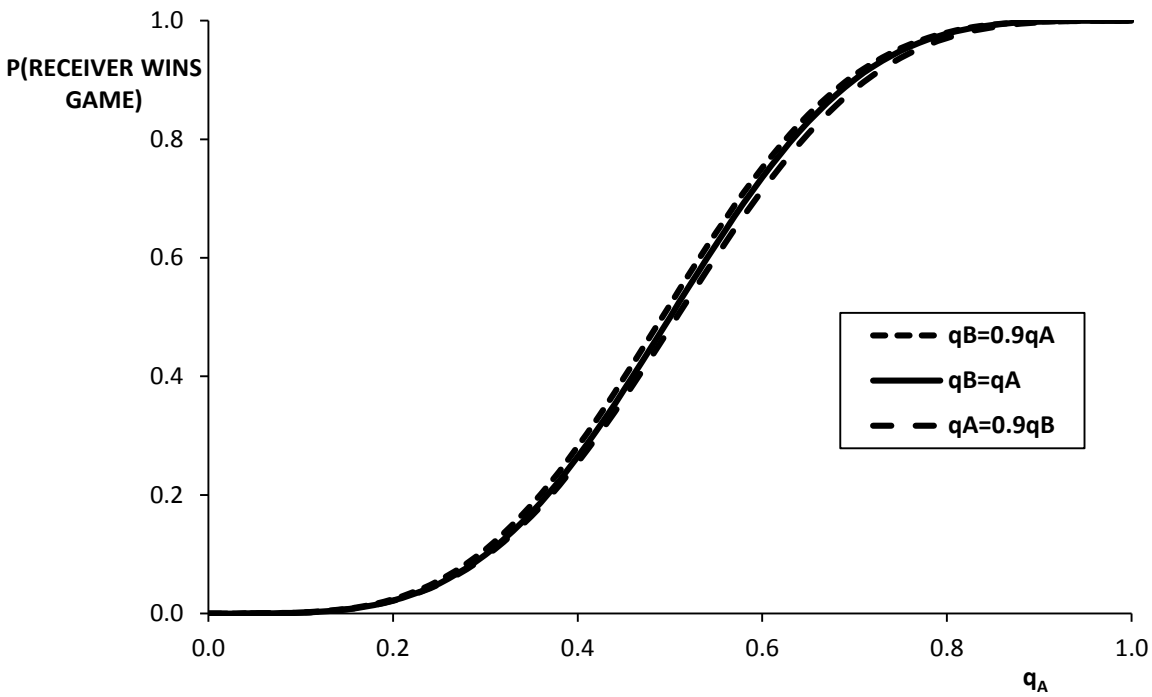


Figure 3. Probability of holding serve when stationarity can be assumed and in two cases of when it is violated.

In the case of a player such as Federer who wins a lower proportion of break points than non-break points, the maximum difference in the probability of breaking serve over when stationarity is assumed is 0.021. In the case of a player such as Nadal who wins a higher proportion of break points than non-break points, the maximum difference in the probability of breaking serve over when stationarity is assumed is 0.022. These differences are equivalent 1 break of service in 45 or 46 receiving games which is one extra break of serve in three 6-4, 6-4, 6-4 matches. While the models of winning tennis games may be robust, there are implications for tennis players when playing break points. There is a general concept of opposition effect on sports performance (McGarry and Franks, 1994; Grehaigne *et al*., 1996; Tenga et al., 2010a, 2010b). Therefore, a serving player's performance will be effected by the play of the receiving player which may be of a higher or lower quality during break points than during non-break points.

The current investigation does have some imitations that the author acknowledges. The study used matches for the 2011 US Open and the results cannot be generalised to the French Open where there are more breaks of serve or to Wimbledon where there are fewer breaks of serve (Knight and O'Donoghue, 2012 In Press). The criteria of at least 5 break points for each player in a match has excluded performances where players do not achieve break points. These are legitimate tennis performances and their exclusion may have resulted in the proportion of points win when returning being over-estimated.

The different scoreline effects found in the two studies reported in this paper relate to point outcomes. Future research is required to examine scoreline effects on tactical aspects of play. Aspects of play that could be considered in future studies of break points and non-break points include net play (Brown and O'Donoghue, 2008), serve direction (Unierzyski and Wieczorek, 2004) and shot placement (Hughes and Clarke, 1995). As well as looking at

break-points, future research into scoreline effects should look at game points for the server as well as those points shown to be the most important according to mathematical models (Morris, 1977; Croucher, 1986; Klaasen and Magnus, 2001; Pollard, 2004). Future research should also distinguish between receiving points played where matches are in different set scores (games won by each player) and match scores (sets won by each player).

## 5. Conclusions

In men's singles tennis at the US Open, winning players win a significantly greater proportion of break points than non-break points when receiving serve. Those players who lose these matches win a similar proportion of break points as non-break points. A study of the World's top four men's singles players revealed scoreline had different effects on different players. Novak Djokovic won a similar proportion of break points to non-break points. However, Rafael Nadal won a greater proportion of break points than non-break points while Andy Murray and Roger Federer won a lower proportion of break points than non-break points. The findings of these two studies challenge the assumption of stationarity used in models of winning games of tennis.

## 6. Practical application

Players who win different proportions of points in different scoreline states may not be performing as well as they could in all situations. This can be viewed from the server's point of view or from the receiver's point of view. Where receiving players win a lower proportion of non-break points than break points, it may be that they are less motivated at game scores of 40-0, 40-15 and 30-0. If these players focussed equally on all points it could lead to more break point opportunities. Where a player wins a lower proportion of break points than non-break points there may be psychological factors that need to be addressed. These critical points are high pressure situations and the conversion of break points can lead to sets being won in tennis. Similarly, a break point is a critical situation for the serving player. Where serving players win a lower proportion of break points against their serve than other service points, they could lose sets as a result. There may be psychological aspects of critical points on serve that need be addressed. When a player wins a higher proportion of break points against his serve than other serving points, serving games may be longer than they need to be. Preventing breaks of serve is clearly important but if players are facing many break points then they could be winning fewer points earlier within service games. This could lead to fatigue within individual matches as well as tournament situations. Coaches and other support staff should help players perform equally on all service points and all receiving points.

## 7. Acknowledgement

The author wishes to thank Zsófia Csomor who gathered the internet data used in the current investigation.

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