The Relationships between the Normative Performance Profiles and the Winning of Sets in Women’s Singles Matches of Professional Tennis

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The purpose of this study was to investigate the relationships between the normative performance profiles proposed by O’Donoghue (2005) and the winning of sets in actual women’s singles matches of professional tennis. Twenty-four matches from 2010 and 2011 US Open tournaments were analyzed with 13 performance indicators. The normative performance percentiles were calculated and the total sums of percentile values were compared between winners and losers. As a result, the normative performance percentiles are obtained from actual match data. The normative performance percentiles in current study show similar tendencies compared with O’Donoghue’s (2005) data. The normative performance profiles in each match show difference of performance between winners and losers of sets visually. The difference of the total sum of percentile values between winner and loser significantly depends on types of set scores. That is, large difference in set scores show large difference of the total sum of percentile values. It suggests that the total sum of percentile values have large difference between winners and losers, resulting in an overwhelming victory. It is concluded that the difference of the total sum of percentile values have positive correlation with difference of set scores between winners and losers.

Keywords: normative performance profiling, match analysis, percentiles, tennis

1. Introduction

In recent years, performance profiling technique have been focused on for evaluating sports performance. Hughes et al. (2000) introduced performance profiles to standardize players’ performance and to evaluate players’ performance with standardized profiles. Hughes et al. (2001) proposed minimum numbers of matches required to stabilize performance within a given percentage. They suggested that the minimum numbers of matches in racket sports to stabilize performance were four to eight. James et al. (2005) proposed performance profiling technique with 95 per cent confidence intervals for the median to evaluate rugby players’ performance.

O’Donoghue (2005) proposed normative performance profiling technique with norms of each performance indicator. The objective of the normative performance profiles was to characterize the players’ typical performance. This technique could evaluate characteristics of players’ performance relatively in specific population. This technique was useful for coaches and players because the results were shown visually with a radar chart. They can easily understand their performance in certain population that they are interested in.

However, O’Donoghue (2005) just proposed the technique of normative performance profiling and only characterized players’ performance. It remains to validate whether this technique can evaluate players’ actual performance. O’Donoghue (2013) also suggested that this technique had issues about influences by quality of opponents. O’Donoghue et al. (2008) adjusted this issue by separating norms for different types of matches. The matches were classi-
fied as four types, between 2 teams in top half of the league, between a team in the top half against bottom half, between a team in the bottom half against top half or between 2 teams in bottom half. O’Donoghue (2013) also indicated a fine-grain approach to addressing opponent quality by Cullinane and O’Donoghue (2011). Those adjustments were necessary for producing typical and individual performance.

In current study, the authors focus on evaluating the performance of between winners and losers in an actual set with O’Donoghue’s (2005) technique. The purpose of this paper is to investigate relationships between the normative performance profiles by O’Donoghue (2005) and the winning of sets in actual women’s singles matches of professional tennis.

2. Methods

2.1. Data collection

Data were collected from women’s singles matches in 2010 and 2011 US Open tournaments. Total numbers of matches were twelve and total numbers of sets were twenty-seven. Three sets with imperfect data were eliminated from this study. Therefore twenty-four sets are used in this investigation. Hughes et al. (2001) suggested the minimum numbers of matches necessary to produce performance profiles were four. Hence the number of matches in this paper is validated. One match contained two players’ performance, so it follows that forty-eight kinds of performance are analyzed. The computerized scorebook for tennis (Takahashi et al., 2006) was used for data collection.

2.2. Performance indicators

14 indicators are selected by referring to O’Donoghue (2005), Takahashi and Nishinakama (2013), and Takahashi et al. (2010b).

O’Donoghue (2005) used 12 indicators in order to propose the normative performance profiles. Those 12 indicators were generally used as ‘Stats’ in several tournaments. O’Donoghue (2005) gathered those data from websites of tournaments. The indicators were limited to ‘Stats’ on such websites.

Takahashi and Nishinakama (2013) proposed the normative performance profiles with 16 indicators. They used the computerized scorebook for tennis for this data collection. Those 16 indicators were calculated from those data. It needs some procedures for calculation. And, as their conclusion, it is possible to evaluate players’ performance by selecting appropriate indicators.

Takahashi et al. (2010b) developed a function called ‘stats’ of the computerized scorebook for tennis. It can calculate 17 indicators automatically. This function provides those data in a real-time manner. Those indicators are useful for real-time analysis and feedback.

In this study, we adopt 14 indicators based on the results of Takahashi et al. (2010b). The selected indicators are as follows.

1) %1stIn: The percentage of first serves that was in.
2) %Aces: The percentage of serve ace per set.
3) DF/Game: The mean of double faults per game (n)
4) %1stWon: The percentage of points won per set when first serve was in.
5) %2ndWon: The percentage of points won per set when second serve was in.
6) Inter-shot time of 1st: The mean of inter-shot time of first serve (s).
7) Inter-shot time of 2nd: The mean of inter-shot time of second serve (s).
8) %Won1stR: The percentage of points won per set when receiver returned opponent’s first serve.
9) %Won2ndR: The percentage of points won per set when receiver returned opponent’s second serve.
10) %BP/Set: The percentage of break points played per set.
11) %BPW: The percentage of break points converted per set.
12) %Winners: The percentage of points won when the player hit a winner including serve ace.
13) %NetPts: The percentage of points when the player playing at the net.
14) %NetWon: The percentage of points won when the player playing at the net.

The indicators with underlines are newly adopted in this study. DF/Game tries to evaluate consistency of second serve. O’Donoghue (2005) used %DF, the percentage of service points where the player made double faults, as an indicator of the same type.
Takahashi and Nishinakama (2013) also used % 2ndIn for evaluating second serve that was in. The ‘stats’ function of the computerized scorebook for tennis calculates the numbers of double faults and of serve games played by each player. The value of DF/Game can be calculated easily by the ‘stats’ function.

We can collect the inter-shot time data (Takahashi et al., 2006) on the computerized scorebook for tennis and, therefore, two types of inter-shot time of serve are adopted as indicators. Inter-shot time of serve means time intervals between impact of serve and the return when the serve was in. Those types of indicators were also adopted in O’Donoghue (2005) as V1 or V2, the mean of the first or second serve speed, respectively.

The indicators of points won by receivers, %Won1st(2nd)R, are adopted in this study. Those indicators try to evaluate players’ performance in return games. They also can be calculated easily by the ‘stats’ function.

The indicators about net play, %NetPts or %NetWon, try to evaluate when players were playing at the net. The ‘stats’ function categorized net-play as that when a rally was finished by volley or smash of the players as well as pass or lob of opponents.

The rest of indicators appeared in O’Donoghue (2005) as well as Takahashi and Nishinakama (2013). Those indicators are considered as basic criteria for evaluating players’ performance.

Matches for investigation were selected from 2010 and 2011 US Open tournaments. To clarify the data stability within the years, the difference of each indicator between the years are verified by Mann-Whitney U test. Only one indicator, inter-shot time of 2nd, shows significant difference (p<0.05) between the results of 2010 and 2011, meaning that this indicator is not stable in those two years. Therefore, inter-shot time of 2nd is eliminated from constructing performance profiles in this study. Conclusively, the normative performance profiles in this study are based on 13 indicators collected from 2010 and 2011 US Open tournaments.

2.3. Proposing the normative performance profiles

In order to propose the normative performance profiles, we followed the procedures proposed by O’Donoghue (2005). At first, the normative performance percentiles for each of the performance indicators were determined as the 19 percentiles from 5 % to 95% in steps of 5% from actual sets data. The next step was to construct a normative performance profile on each target subject. The performances on each subject is represented as a set of the normative performance percentiles of the indicators. The last step was to indicate the performance in a radar chart as the normative performance profiles.

2.4. Relationships between the normative performance profiles and the winning of sets

To investigate relationships between the normative performance profiles and the winning of sets, difference of the total sum of the percentile values (the total percentiles, in short) between the winner and the loser of each set was calculated. Our equation of such difference of the percentiles is as follows:

\[
\text{Difference of the percentiles} = (\text{The total percentiles of the winner}) - (\text{The total percentiles of the loser}) / 5
\]

If difference of the percentiles is positive, then it means that the total percentiles of the winners are larger than those of the losers. Since we expect difference of percentiles to indicate how much steps (of 5%) were different between winners and losers, it is divided by five, the number of steps of percentiles.

3. Results

3.1. The normative performance percentiles and the normative performance profiles

The normative performance percentiles are determined as Table 1. Values of each indicator are sorted so that lower rows may show better performance. Most indicators are arranged in ascending order of values, while the two exceptional ones, DF per game and inter-shot time of 1st are shown in descending order. Several consecutive cells, colored by gray, have the same value in the columns, %Aces, DF/Game, %BPW or %NetWon. If any performance is included in such a set of the same value then its percentile is determined as the median of those ones in the corresponding rows. Examples of the normative performance profiles for winners and losers are shown in Figures 1 and 2.
Table 1  The normative performance percentiles of 13 performance indicators from 2010 and 2011 US Open tournaments.

| Percentile | %1stIn | %Aces | DF/Game (to) | %1stWon | %2ndWon | Inter-shot time of 1st (s) | %Won1stR | %Won2ndR | %BP/Set | %BPW | %Winners | %NetPs | %NetWon |
|------------|--------|-------|--------------|---------|---------|--------------------------|---------|---------|---------|-----|----------|-------|---------|
| 5          | 50.0%  | 0.0%  | 0.82         | 47.6%   | 15.1%   | 1.23                     | 19.2%   | 22.2%   | 0.0%    | 0.0%| 5.1%     | 1.9%  | 29.4%   |
| 10         | 53.1%  | 0.0%  | 0.69         | 50.0%   | 18.2%   | 1.05                     | 21.0%   | 33.3%   | 2.2%    | 0.0%| 6.9%     | 3.5%  | 47.0%   |
| 15         | 54.4%  | 0.0%  | 0.60         | 51.6%   | 21.5%   | 1.01                     | 22.7%   | 40.1%   | 4.1%    | 25.0%| 7.3%     | 3.9%  | 50.0%   |
| 20         | 57.2%  | 0.0%  | 0.60         | 53.3%   | 23.3%   | 0.98                     | 24.3%   | 45.1%   | 5.1%    | 28.6%| 7.6%     | 4.5%  | 50.0%   |
| 25         | 59.0%  | 0.0%  | 0.50         | 56.0%   | 30.1%   | 0.97                     | 26.3%   | 50.0%   | 5.5%    | 33.3%| 8.7%     | 4.8%  | 57.1%   |
| 30         | 61.0%  | 0.0%  | 0.50         | 57.6%   | 33.3%   | 0.94                     | 28.6%   | 50.0%   | 7.1%    | 33.3%| 11.6%    | 5.5%  | 57.4%   |
| 35         | 62.5%  | 1.0%  | 0.50         | 59.8%   | 33.3%   | 0.93                     | 29.4%   | 51.7%   | 7.3%    | 40.6%| 12.2%    | 5.8%  | 60.0%   |
| 40         | 63.8%  | 2.5%  | 0.35         | 62.2%   | 35.8%   | 0.93                     | 33.0%   | 54.4%   | 7.7%    | 50.0%| 12.9%    | 6.4%  | 61.8%   |
| 45         | 64.3%  | 2.9%  | 0.25         | 62.8%   | 37.9%   | 0.92                     | 33.3%   | 55.7%   | 8.7%    | 50.0%| 13.2%    | 7.0%  | 66.7%   |
| 50         | 65.3%  | 3.4%  | 0.25         | 65.0%   | 43.2%   | 0.90                     | 35.0%   | 56.8%   | 10.8%   | 50.0%| 13.3%    | 8.5%  | 66.7%   |
| 55         | 66.7%  | 3.7%  | 0.21         | 66.7%   | 44.3%   | 0.87                     | 37.2%   | 62.1%   | 11.4%   | 50.0%| 13.5%    | 9.1%  | 75.0%   |
| 60         | 66.9%  | 4.4%  | 0.20         | 67.0%   | 45.6%   | 0.86                     | 37.8%   | 64.2%   | 12.7%   | 53.3%| 13.6%    | 9.5%  | 76.0%   |
| 65         | 68.8%  | 5.0%  | 0.18         | 70.6%   | 48.3%   | 0.85                     | 40.2%   | 66.7%   | 13.7%   | 66.7%| 14.2%    | 9.9%  | 82.7%   |
| 70         | 69.9%  | 5.2%  | 0.17         | 71.4%   | 50.0%   | 0.85                     | 42.4%   | 66.7%   | 15.4%   | 66.7%| 14.6%    | 10.8%| 85.7%   |
| 75         | 71.8%  | 7.3%  | 0.17         | 73.7%   | 50.0%   | 0.84                     | 44.0%   | 69.9%   | 15.7%   | 75.0%| 15.1%    | 12.4%| 91.7%   |
| 80         | 72.7%  | 8.0%  | 0.00         | 75.7%   | 54.9%   | 0.83                     | 46.7%   | 76.7%   | 16.5%   | 78.0%| 15.3%    | 13.2%| 100.0%  |
| 85         | 74.9%  | 8.1%  | 0.00         | 77.3%   | 59.9%   | 0.81                     | 48.4%   | 78.5%   | 18.0%   | 99.0%| 15.5%    | 13.3%| 100.0%  |
| 90         | 77.0%  | 10.7% | 0.00         | 79.0%   | 66.7%   | 0.80                     | 50.0%   | 81.8%   | 20.8%   | 100.0%| 18.0%    | 14.5%| 100.0%  |
| 95         | 78.4%  | 14.3% | 0.00         | 80.8%   | 77.8%   | 0.76                     | 52.4%   | 84.9%   | 25.0%   | 100.0%| 22.9%    | 15.9%| 100.0%  |

M 65.0%  4.4%  0.35  64.8%  42.3%  0.93  35.2%  57.7%  11.2%  52.5%  13.0%  8.5%  70.0%  
SD 0.0924  0.0491  0.367  0.1156  0.1965  0.163  0.1156  0.1965  0.0736  0.3096  0.0580  0.0476  0.2518

Figure 1  An example of the normative performance profile for a pair of winner and loser of a set. The winner won this set by 6-3.
Figure 2  An example of the normative performance profile for a pair of winner and loser of a set. The winner won this set by 7-5.

Table 2  The total percentiles between winners and losers in ascending order of difference.

| Set no. | Score | Winner’s total percentile | Loser’s total percentile | Difference |
|---------|-------|---------------------------|--------------------------|------------|
| 1       | 6-4   | 520                       | 650                      | -26        |
| 2       | 7-5   | 605                       | 640                      | -7         |
| 3       | 6-3   | 715                       | 730                      | -3         |
| 4       | 7-6(2)| 690                       | 690                      | 0          |
| 5       | 6-4   | 705                       | 655                      | 10         |
| 6       | 7-5   | 685                       | 620                      | 13         |
| 7       | 7-5   | 695                       | 625                      | 14         |
| 8       | 7-5   | 650                       | 530                      | 24         |
| 9       | 6-4   | 710                       | 585                      | 25         |
| 10      | 6-3   | 720                       | 565                      | 31         |
| 11      | 7-6(8)| 770                       | 585                      | 37         |
| 12      | 7-6(5)| 755                       | 565                      | 38         |
| 13      | 6-4   | 810                       | 590                      | 44         |
| 14      | 6-3   | 695                       | 450                      | 49         |
| 15      | 6-4   | 855                       | 605                      | 50         |
| 16      | 6-3   | 790                       | 540                      | 50         |
| 17      | 6-3   | 860                       | 560                      | 60         |
| 18      | 7-5   | 840                       | 525                      | 63         |
| 19      | 6-4   | 865                       | 580                      | 67         |
| 20      | 6-2   | 870                       | 460                      | 82         |
| 21      | 6-2   | 890                       | 420                      | 94         |
| 22      | 6-2   | 955                       | 435                      | 104        |
| 23      | 6-1   | 930                       | 340                      | 118        |
| 24      | 6-1   | 1030                      | 410                      | 124        |

Table 3  The results of Mann-Whitney U test with Bonferroni correction for the difference of the total percentiles among three types of set scores, where * denotes p < 0.167.

| Type of set score | N  | Mean difference | SD  | Significance level    |
|-------------------|----|-----------------|-----|-----------------------|
| Close             | 14 | 24.4            | 25.6| Close vs Middle: n.s. |
| Middle            | 5  | 37.4            | 24.9| Middle vs Large: *    |
| Large             | 5  | 104.4           | 17.2| Large vs Close: *     |

3.2. Relationships between the normative performance profiles and the winning of sets

The total percentiles and difference of total percentiles between winners and losers are shown in Table 2. They are sorted in ascending order. Figure 3 shows difference of total percentiles of each set in ascending order. The vertical bars are colored to show how close the score of each set is. The black ones show large difference in score such as 6-0, 6-1 or 6-2 (called large difference sets). The gray ones represent close score such as 6-4, 7-5 or 7-6 (called close difference sets). The white ones denote middle difference in score such as 6-3 (called a middle difference set). The values of difference of total percentiles are verified by Mann-Whitney U test with Bonferroni correction (Table 3). A significant feature distinguishing large difference sets from the other two
4. Discussion

4.1. Applicability of the normative performance profiling technique to evaluation of the winning of the actual sets

Table 1 shows the normative performance percentiles in women’s singles matches in 2010 and 2011 US Open tournaments. O’Donoghue (2005) also indicated the normative performance percentiles in 2002 Grand Slam tournaments. Most of indicators in these two studies have similar tendencies, implying that we can consider the data of the current study to be appropriate.

Some indicators have values that are different from those in O’Donoghue’s (2005) study. For example, %NetPts in O’Donoghue’s (2005) study is higher and %NetWon in his study is lower than our values. These results show characteristics of the indicators about net play. We consider that this is because those indicators reflect characteristics of court surfaces as well as change of role of net play in women’s singles matches.

All matches appeared in O’Donoghue (2005) were taken from Grand Slam tournaments in 2002. Those data included four types of court surfaces containing lawn courts in Wimbledon tournament, and it is reported that, in Wimbledon, players took advantage of net play even in women’s singles matches (Takahashi et al., 2010a). This explains variation in %NetPts data.

Additionally, the play pattern has changed between 2002 and 2010-2011. Women tended to rally at baseline more than men (O’Donoghue and Ingram, 2001). And inter-shot time of ground strokes became shorter in 2000s in those of 1980s and 1990s (Takahashi et al., 2009). These past studies indicated that ground strokes in women’s singles matches got more important in 2010-2011 than in 2002. Therefore players in recent years select net play only in certain advantageous situations where winning the point can be expected as a result of baseline rallies.

Figures 1 and 2 shows an example of the normative performance profiles for winner and loser of a set. The winner’s profile forms a larger radar chart than that of the loser in Figure 1. It shows large difference of total percentiles in a middle difference set. Figure 2 shows close difference in close difference set. We cannot judge visually which radar is larger. O’Donoghue (2005) only proposed the normative performance profiles as a summary of players performance with mean, SD and quartile ranges. The objective of the normative performance profiles by O’Donoghue (2005) were to indicate typical performance of individuals. However, Figures 1 and 2 suggest that the normative performance profiles can evaluate performance of players in actual sets and compare performance of winners and losers.
4.2. Relationship between the normative performance profiles and the winning of sets

We try to represent players’ performance by means of the total percentiles. It is indicated in Takahashi et al. (2013) that this is possible. Table 2 shows all results of the total percentiles and their difference between winners and losers. Figure 3 also shows difference the total percentiles between winners and losers in ascending order. Large difference sets show large differences in the total percentiles, while middle or close difference sets give considerably smaller difference in the total percentiles than the large difference sets. Statistical results are presented in Table 3.

It seems that the normative performance profiles depend on performance of the whole players in specific population that we are interested in, and the percentile values of each indicator shows the performance levels of players in this population. Therefore, we can expect that the total percentiles represent the whole performance of players in this population.

Difference of the total percentiles between winners and losers depends on types of sets. There is significantly large difference of total percentiles between winners and losers in large difference sets. These results suggest that difference of the total percentiles have relationships with set scores. It is observed that, as difference of the total percentiles between winners and losers got larger, difference in score of a set increases.

No significant differences of total percentiles appeared in middle or close difference sets.

On the other hand, based on more than 150 sets taken from men’s singles matches, Takahashi et al. (2013) reported that each of the three types of sets has different tendency in the total percentiles. There is significant difference of total percentiles between any pair of the three types of sets.

It is left for future research to investigate whether or not similar tendency appears in women’s singles matches by means of a set of large data.

5. Conclusion

This study is to investigate relationships between the normative performance profiles proposed by O’Donoghue (2005) and the winning of sets in actual women’s singles matches of professional tennis. It is observed that the total percentiles help represent whole player’s performance. Difference of the total percentiles can reflect difference of whole performance between winners and losers. In addition, it has relationships with set scores. This is because, as difference of the total percentiles becomes larger, set score gets overwhelming.

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