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Research on the Motivation of Competition Situation Changes Based on the Performance Score and Momentum Scoring Model

Pingxin Liu, Maoliang Tian*, Chenzhe Dang

Dalian Maritime University, Dalian, China, 116000

* Corresponding Author Email: maoliangtian0@dlmu.edu.cn

Abstract. Momentum in sports, particularly in tennis, refers to the perceived shift in performance and psychological advantage that can influence the outcome of a match. It encompasses both physical and psychological aspects and is often characterized by sequences of winning points, games, or sets. In tennis match, the flow of the match tends to change based on athlete's individual ability, real-time status and other objective factors.In these factors, a growing number of matches have shown that the effect of momentum is particularly important. To explore the influence of momentum on the flow of the match,on the one hand,the paper establishes Player's Performance Score Model and uses it to describe the flow of match.On the other hand, the paper establishes a Momentum Scoring Model to assess the impact of momentum on the outcome of the game.

Keywords: Momentum; tennis; Performance Score; Factor Analysis; AHP.

1. Introduction

The Performance Score Model is based on factor analysis. Firstly, analyzing and treating briefly the data that emerged from the tennis match, then obtaining fourteen indicators. The paper derives three main factors(including 10 effective elements) through analyzing several games' data and generating a scree plot,and then establishes the Performance Score Model and plots the two players' situation analysis graphs, which yield results consistent with the actual game scores.

The most representative final data were selected, we utilize the Analytic Hierarchy Process and Entropy Weight Method to calculate the weight of each indicators. Simultaneously, we coupled the Analytic Hierarchy Process and Entropy Weight Method through the Lagrange multiplier operator to obtain the optimal weights. So that we can establish model and get the momentum score of player in different moment then access the momentum influencing to the outcome of a match through momentum score curve.

2. Tennis Player's Performance Score Model

2.1. Selection of Technical Indicators

In tennis, there are a number of technical indicators that can have a significant impact on the outcome of a match in different ways[1]. The paper analyses the match data of each player given by Committee and chooses fourteen technical statistical indicators for singles matches, which are divided into the following three categories according to different technical aspects[2]:Serving Phase: First Serve Percentage (FSP), First Serve In (FSI), Second Serve Points Won (SSP), ACE Rate (AR), Double Faults Rate (DFR), Break Points Faced (BPF), Break Points Saved (BPS), Service Games Won (SGW).Returning Phase: Return Games Won (RGW), Break Points Percentage (BPP).Scoring Phase:Total Service Points Won (TSPW), Total Return Points Won (TRP), Total Points Won (TPW)

2.2. Factors Analysis

Before conducting the Factor Analysis, observation of the selected indicators reveals that the DFR and BPF occurring in a service game are both negative indicators. The values for both are better when they are lower. For the other indicators, the higher the values, the better, as they are all positive indicators. In order to ensure that all indicators contribute positively to the overall score in factor analysis, it is necessary to use a negation method to transform the aforementioned two negative indicators into positive ones firstly, ensuring that all selected indicators follow the same trend[3].

While conducting the first Factors Analysis, According to the analysis results, The factor loading of the four indicators(FSP,BPS,BPP,NPW) are less than 0.6,which should then be deleted[4]. Subsequently Factor analysis was performed again, From the results of the second factor analysis, it can be concluded that all indicators meet the criteria and can be retained in this instance. The final results include ten indicators for the technical indicator system in the analysis of factors affecting tennis matches. These are FSI, SSPW, AR, DFR, BPF, SGW, RGW, TSPW,TRPW, TPW.

Factor analysis was conducted once more for the ten indicators finally selected. KMO and Bartlett's spherical test were chosen for descriptive statistics, principal component method was chosen for the extraction of the common factors, the criterion for extracting the factors was the eigenvalue greater than 1[4]. The rotation method was based on the maximum variance method, and regression method was chosen for the calculation of the factor scores.[5]

2.3. KMO and Bartlett's Test of Sphericity

After testing, the value of KMO is $0.673>0.6$. This indicates that the ten selected indicators have strong correlations and weak bias correlations, which are very suitable for factor analysis. The results of the Bartlett's test of sphericity are $P<0.01$.[6]

2.4. Extract Original Variables

The initial information extracted for RGW, TSPW, TRPW, TPW are all greater than 0.9. This suggests that they can all be expressed very well by the common factor. The initial information extracted for FSI, DFR, SGW are between 0.75 and 0.9. They can also be well expressed by the common factors and for extracting the initial information.

AR, SSPW, BPF are between 0.6 and 0.75. Although the initial information extracted by the common factors is not entirely complete and there exists some loss, as all values are greater than 0.6, it indicates that all of them can be expressed. Overall, the information extracted from these ten indicators is relatively complete, and they can all be well expressed by the common factors, meeting the requirements for factor analysis.

2.5. Proportion of Explained Variance

Among the selected ten indicators, the eigenvalues of the first three factors exceed 1, and the cumulative variance contribution rate reaches 83.167%. Therefore, the first three factors are extracted as the principal factors, respectively. The variance contribution rate of Serving Phase is 44.070%, that of Returning Phase is 26.487%, and that of Scoring Phase is 12.609%.

As observed in Fig 1: Scree Plot, the slopes associated with the first three factors are quite steep, but from the fourth factor onwards, the slope gradually flattens out. It means that the error value comes to the minimum when iterating to the third generation.Hence, it is highly reasonable to choose the first three factors as the principal factors.

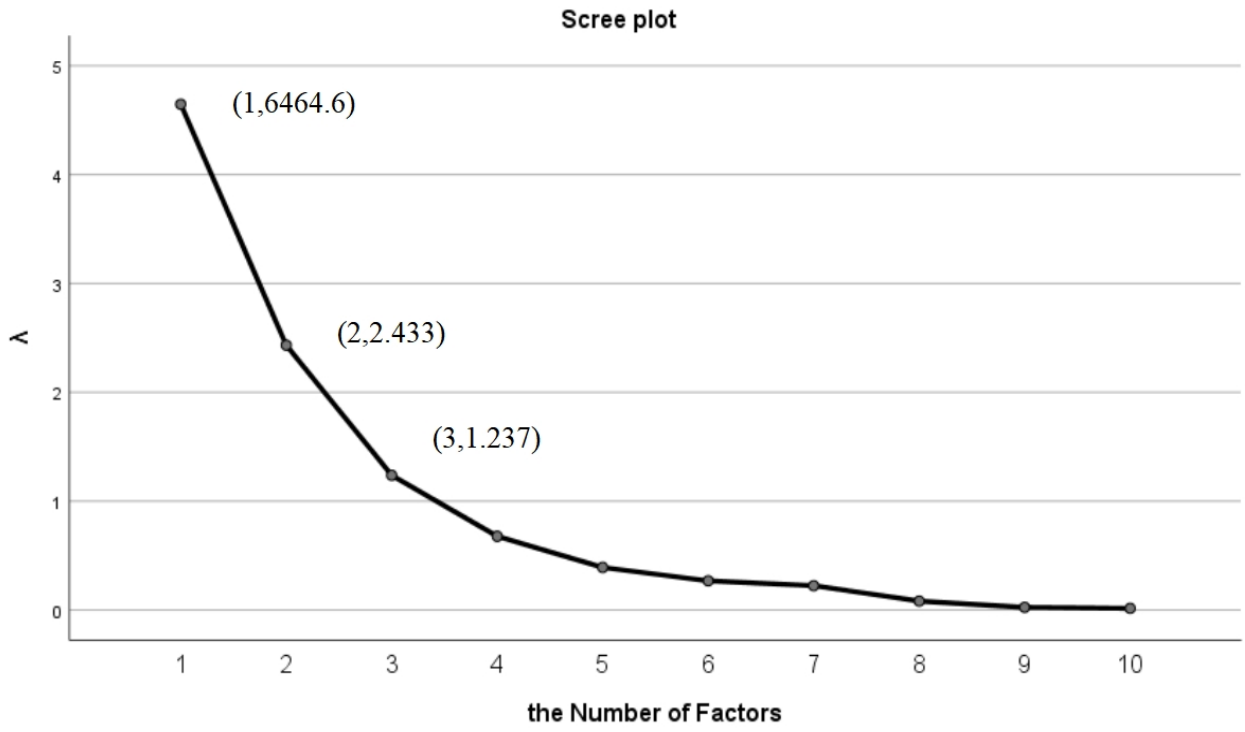

Fig. 1 Scree Plot

2.6. Common Factor Loading Coefficients.

As is shown in Table 6. In Factor 1(F1), there is a high loading on indicators such as the FSI(Q2), SSPW(Q3), BPF(Q6), SGW(Q8), RGW(Q9), TSPW(Q12), TTW(Q14). In Factor 2(F2), there is a high loading on indicators such as RGW(Q9), TRPW(Q13), TPW(Q14). In Factor 3(F3), there is a high loading on indicators such as DFR(Q5).

The analysis indicates that the representative indicators of the three extracted common factors are not significantly prominent, and the meaning of the common factors is not clear and cannot be well explained. Therefore, it is necessary to rotate the three selected common factors using the Varimax Method in order to better interpret the extracted factors.

2.7. Factor Rotation

After rotation, Rotation Factor 1(F1rotation) exhibits high loadings on indicators such as the FSI, SSPW, AR, BPF, SGW, TSPW and TTW. Since these indicators are used to measure performance in service games, therefore, they are named the ‘Service Game Performance Factor’. Rotation Factor 2(F2rotation) exhibits high loadings on indicators such as the RGW, TRP and TPW. Since these indicators are used to measure players' performance in return games, they are therefore named the "Return Game Performance Factor". Rotation Factor 3(F3rotation) exhibits high loadings on indicators like the DFR. This indicator can be used to measure the consistency of a player's serve, and thus it is named the "Serve Consistency Factor". And F1rotation, F2rotation and F3rotation represent the rotated common factors obtained from common factors F1, F2 and F3 after rotation using the Vartimax Method. We can clearly observe the factors which distribute in Fig 2(Q1,Q2,Q3 and so on indicates the 14 factors).

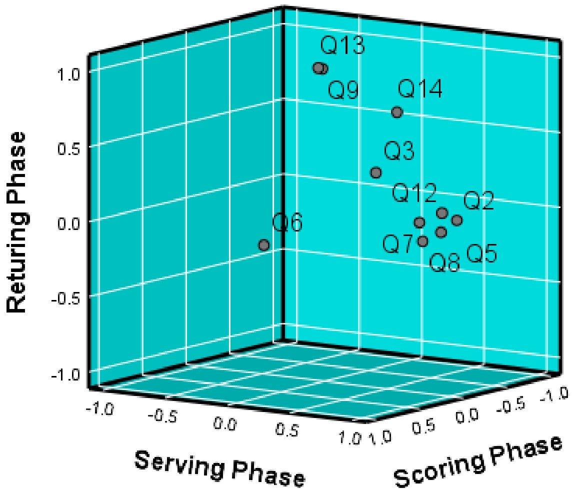

Fig. 2 Factor plot in rotated space

2.8. Factor Score

Based on the factor score coefficients obtained, calculate the total score for the influencing factors in a tennis match.The calculation formula is as follows:

$$F_{1\,total\,score} = 0.156AR + 0.213FSI + 0.127SSP + 0.210SGW - 0.066RGW + 0.223TSPW - 0.0.69TRPW + 0.103TPW + 0.016DFR + 0.192BPF \quad (1)$$

$$F_{2\,total\,score} = -0.062AR - 0.034FSI + 1.010SSP - 0.086SGW + 0.385RGW - 0.014TSPW + 0.388TRPW + 0.259TPW - 0.075DFR - 0.036BPF \quad (2)$$

$$F_{3\,total\,score} = -0.407AR - 0.219FSI + 0.265SSP + 0.095SGW - 0.075RGW + 0.016TSPW - 0.045TRPW + 0.010TPW + 0.706DFR + 0.062BPF \quad (3)$$

$$F_{total\,score} = (0.44070\,F_{1\,total\,score} + 0.26487\,F_{2\,total\,score} + 0.12609\,F_{3\,total\,score}) / 0.83167 \quad (4)$$

$F_{1\,total\,score}$ represents 'Service Game Performance Factor Score', $F_{2\,total\,score}$ represents 'Return Game Performance Factor Score', $F_{3\,total\,score}$ represents 'Serve Consistency Factor Score'. $F_{total\,score}$ represents 'Total Score for Influencing Factors in Tennis Match'. In the influencing factors of men's singles matches, the 'Service Game Performance Factor' accounts for 44.070%, the 'Return Game Performance Factor' accounts for 26.487%, and the 'Serve Consistency Factor' accounts for 12.609%.

2.9. Match Situation Analysis

In various such competitions, there is a type of graphic that displays the win probabilities of both competitors. This type of graphic is referred to as a 'Situation Analysis Chart' or 'Match Situation Graph' through such images, the paper can intuitively understand which of the two players has a greater chance of winning.

The paper employs Tennis Player Performance Scoring Model to conduct a situation analysis on any given match. From calculating the total of the performance scores respectively for players and then taking the difference between the two players' performance score, while there is the Fig 3. The vertical axis in the Fig represents the normalized result of Player 1's performance score minus Player 2's performance score. The horizontal axis denotes the rounds (the smallest unit of measurement in tennis matches)in a match . When the vertical axis is negative, it indicates a higher probability of victory for Player 2. The larger the absolute value, the greater the likelihood of Player 2 winning, and vice versa. A steeper slope in the graph suggests that a player has made significant moves that greatly affect the odds of winning the match. Fig 4 is a win probability analysis chart for a specific match in the dataset.

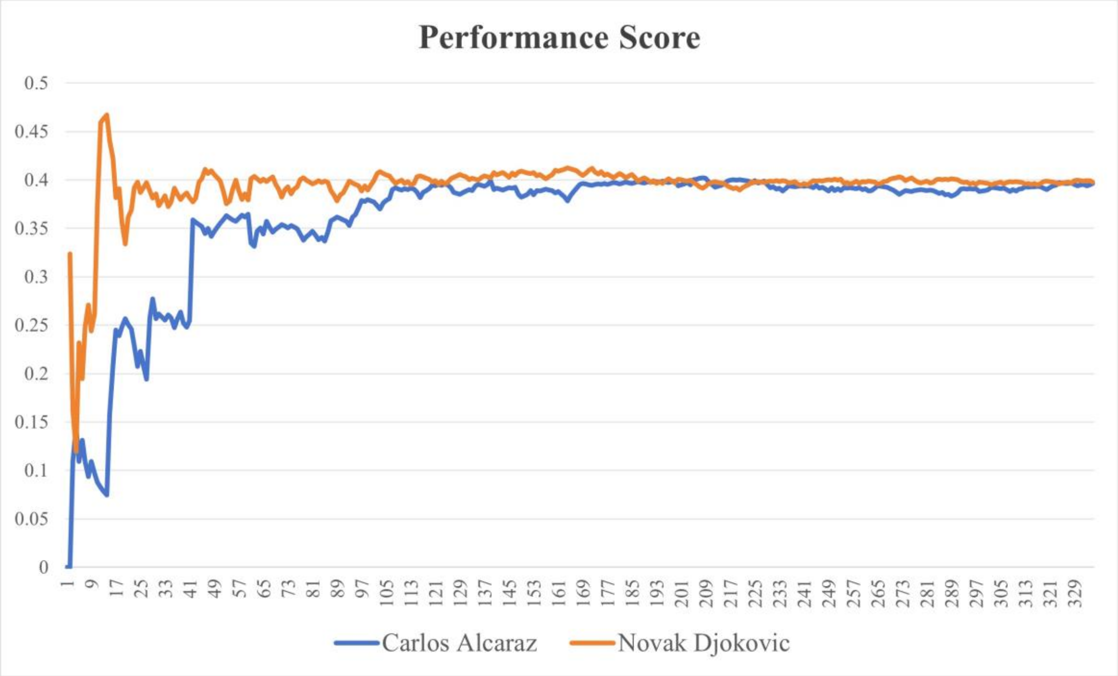

Fig. 3 Player Performance Score Chart

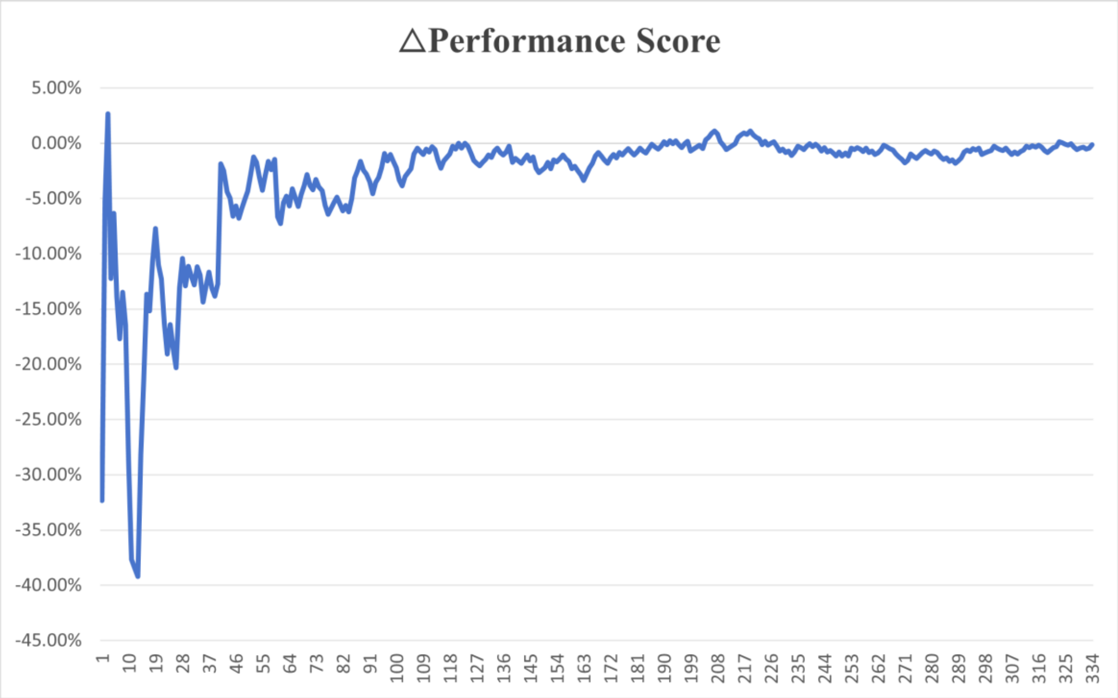

Fig. 4 Situation Analysis Chart

3. Establishment of Momentum Scoring Model

3.1. Standard of the Evaluation Model

A core challenge in AHP is managing the consistency of judgment matrices. [7]Recent studies focus on developing more effective algorithms to calculate the CR, ensuring logical and reliable decision-making processes.[8]

The Player's Momentum Evaluation Model should meet the following criteria:

(1) The developed model should be universal, applicable to various tennis matches and potentially extendable to other ball sports.

(2) The model should be comprehensive, encompassing the influence of different serving, returning, and scoring indicators within tennis matches.

(3) The selected indicators and influencing factors should be reliable and comprehensive, with a requirement for accurate data processing.

3.2. Indicators selection

A tennis player's momentum scoring model is associated with numerous variables, such as the player's psychology, tactical choices, physiology, and the court environment. Among these, the player's psychology is paramount, as fluctuations in mindset can directly affect their momentum. Following that is strategy, where the selection of effective tactics is crucial to the outcome. Next, physiological factors like the player's physical condition, along with environmental influences, must be taken into account[9].

3.3. Calculating of Weights

Weights play a crucial role in the Analytic Hierarchy Process (AHP), reflecting the contribution rate of different indicators.[10] In AHP, the paper uses the Group Decision Making (GDM) method to determine the weights of each indicator. This method requires experts to provide pairwise comparison matrices between different levels, so while GDM is rational, it cannot avoid personal subjective factors.

Firstly, the paper employs the Group Decision Making (GDM) method to subjectively determine the weights of each first-level and second-level indicator. Three experts voted on the importance of four primary indicators for momentum in tennis and ten secondary indicators for primary indicators, with the following specific steps:

(1)Comparisons between different factors

Three experts voted to compare the importance of the main factors.

Psychology>Strategy>Physiology≈Circumstance

(2)Calculating the judgement matrix

With the relationship discussed before, we get our judgement matrix of first-level$(x_{ij})_{4\times4}$.

$$\begin{array}{ccccc} A & B_1 & B_2 & B_3 & B_4 \\ B_1 & 1 & 3 & 5 & 5 \\ B_2 & \frac{1}{3} & 1 & 4 & 4 \\ B_3 & \frac{1}{5} & \frac{1}{4} & 1 & 1 \\ B_4 & \frac{1}{5} & \frac{1}{4} & 1 & 1 \end{array} \quad (5)$$

(3)Consistency test

We can calculate the eigenvalues of the judgment matrix and determine the maximum eigenvalue λmax. This value is then substituted into the consistency test formula to obtain the Consistency Ratio (CR).

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad (6)$$

$$CR = \frac{CI}{RI} \quad (7)$$

Where RI=0.89, when n=4. For the above comparison matrix, we obtain CR=0.0176<0.1, thus the judgement matrix is acceptable.

(4)Calculating to gain weight

After all the judgment matrices pass the consistency test, we solve for the weights of the four first-level indicators corresponding to momentum and the weights of the ten second-level indicators corresponding to their respective first-level indicators: Psychology(0.5482), Strategy(0.2804), Physiology(0.0857), Circumstance(0.0857). Then, we multiply the weights of these two levels of indicators to obtain the composite weight.Secondly**,** we use EWM to find the weights of all secondary indicators. The specific steps to calculate each first-level indicator are as follows:

calculate the probability matrix *p*.

$$p_{ij} = \frac{z_{ij}}{\sum_{i=1}^{n} z_{ij}} \quad (8)$$

calculate the information entropy for each indicator E_j.

$$E_j = -\frac{1}{\ln n} * \sum_{i=1}^{n} p_{ij} * \ln(p_{ij}) \quad (9)$$

calculate entropy weights for each indicator w_j.

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{n}(1 - E_j)} \tag{10}$$

sum the values of each secondary indicator by weight to obtain the value of the primary indicator *b*

$$x_{ik} = \sum_{i=1}^{n} w_j * x_{ij} \tag{11}$$

With the weights of the secondary indicators, we obtain a vector of weights for the primary indicators.

The paper combines the two sets of weights. With the principle of Minimum Relative Information Entropy, establishing an optimization model to minimize the relative deviation of the results under the two decision methods.

$$\min \sum_{j=1}^{n} w_j(\ln w_j - \ln \alpha_j) + \sum_{j=1}^{n} w_j(\ln w_j - \ln \beta_j) \tag{12}$$

$$\begin{aligned} &\sum w_j = 1 \\ &w_j > 0 \\ &j = 1,2,\ldots,n \end{aligned} \tag{13}$$

Lagrange Multiplier Method is used to solve the above optimization problem, and we got the final weights:

$$w_j = \frac{(\chi_j \alpha_j)^{0.5}}{\sum_{j=1}^{n}(\chi_j \alpha_j)^{0.5}} \tag{14}$$

As is shown to Fig 5, we have depicted the results of the AHP evaluation model using a double-layered circular chart, showcasing the weights of ten indicators that influence momentum in a tennis match.

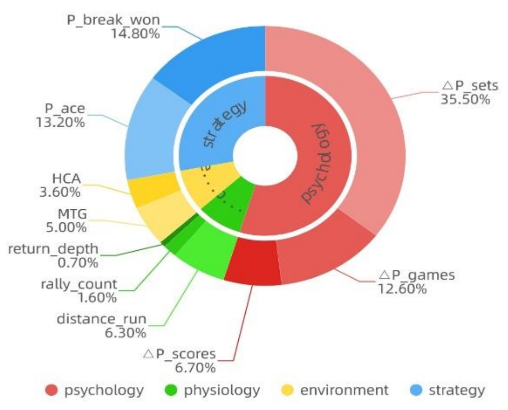

Fig. 5 Weights of secondary indicators

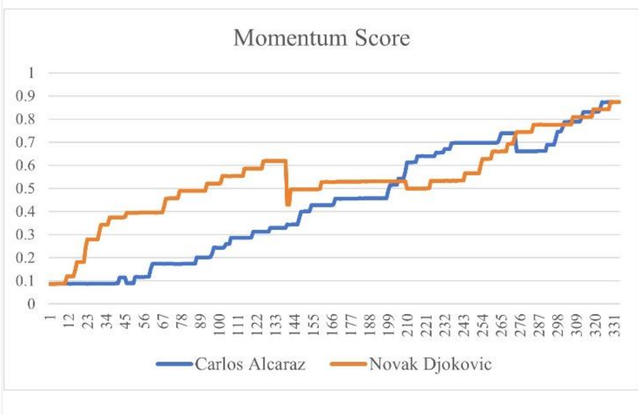

Fig. 6 Two players' momentum score

Subsequently, we established a “Momentum Scoring Model”. (C1-C10 represent 10 factors above)

$$\begin{aligned} A &= 0.342C_1 + 0.131C_2 + 0.075C_3 + 0.132C_4 + 0.146C_5 \\ &+ 0.063C_6 + 0.016C_7 + 0.007C_8 + 0.050C_9 + 0.036C_{10} \end{aligned} \tag{15}$$

After summing and normalizing the data of the selected ten secondary indicators, the obtained scores for each of these indicators at every moment throughout the tennis match. From the research, it is found that the type of court surface and home court advantage in Wimbledon have minimal impact on the momentum score, so we assigned a score of 1 to these two indicators. Subsequently, the paper multiplies these ten indicator scores by their respective composite weights to calculate the momentum score for the tennis player at each moment during the match. As is shown to Fig 6.

4. Conclusions

In establishing the Performance Scoring Model, the calculated 14 indicators across 30 matches, obtaining 60 data sets for each indicator. With a sample size approximately six times the number of variables, the paper achieved highly reliable and accurate results.The model also quantifies the values of psychological and strategic indicators and calculated their weights, thus reasonably deriving the players' performance scores and momentum scores.It can be used to guide the real-time direction of events very well.

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