Performance Evaluation and Analysis in Tennis: A Case Study of Wimbledon 2023 Final

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Abstract. This study employs comprehensive performance evaluation techniques to analyze the Wimbledon 2023 final match between Carlos Alcaraz and Novak Djokovic. Data preprocessing involves categorizing evaluation metrics into two categories and applying normalization methods. This paper describes the fuzzy comprehensive evaluation model to transform qualitative evaluation into quantitative evaluation for comprehensive evaluation. The entropy weight method determines the index weight to increase the credibility of the model. Wavelet analysis is used for signal denoising and performance comparison. Results show variations in player performance over time, highlighting factors influencing match outcomes.

Keywords: Tennis performance evaluation, Data preprocessing, Fuzzy Synthetic Evaluation, Entropy weighting method, Wavelet analysis.

1. Introduction

Wimbledon is one of the top tennis tournaments in the world. Every year, many of the world's top players are attracted to participate in it. At the same time, the final is the embodiment of the top players and the technical level of the competition. In such a tournament, the performance of players is not only affected by technical and physical ability [1-2], but also by the comprehensive influence of psychological quality, game strategy and other factors. Therefore, a comprehensive assessment of the players' performance in the tournament can provide a better understanding of the players' strengths and weaknesses and provide an important reference basis for future tactical planning and training.

In the Wimbledon men's singles final, Carlos Alcaraz and Novak Djokovic displayed different playing styles and performance characteristics. This study aims to address the following questions: how to comprehensively assess the players' performance in the match, including technical indicators, psychological quality and physical condition?

What kind of comprehensive assessment model can be applied to objectively and accurately reflect the differences in players' status and performance during the match? How is the outcome affected by changes in player status during a match? What are the key factors that determine the outcome of the game?

Through the preprocessing and analysis of the performance data of athletes in the competition, the fuzzy comprehensive evaluation model and the information entropy weighting method are used for comprehensive evaluation. and combining with the wavelet analysis model for signal processing and noise rejection, this study aims to dig deeper into the changing law of the players' state in the competition and explore their influencing factors on the results of the competition [3], so as to provide a new idea and method for the assessment of athletes' performances in sports and athletics This study aims to explore the change pattern of the player's state during the game and explore its influence factors on the game results, so as to provide new ideas and methods for the assessment of athletes' performance in sports competition.

2. Visualize performance: Wavelet-Synthetic Evaluation Model

The question asks to capture the flow of the play when scoring occurs, quantitatively analyze the score changes and player performance metrics, visualize the time series of player performance, and determine which player performed better at a given time. The more reasonable the performance metrics, the higher the player rating. In the evaluation, the dominant factors are extracted after orthogonalizing multiple variables to simplify the evaluation index. Subsequently, the weights of the metrics are determined by the entropy method and used to analyze the performance of the players [4]. Finally, wavelet analysis is performed to visualize the player's performance at game time.

2.1. Exploration Analysis and Data Preprocessing

2.1.1. Data Description and Exploratory Analysis

Between “player made it to the net or not ($p_i_net_pt$)” and “player won the point while at the net ($p_i_net_pt_won$)”, *sever* and $point_victor$, there is a deep relative:

According to research, if a player successfully reaches the net during his turn in a match, he has a 70% chance of winning the game. Therefore, only "player made it to the net ($p_i_net_pt$)" and $point_victor$ are retained as the dominant factor evaluation indexes in the answer to this question. It is reasonable to reduce the similar influencing factors to enhance the credibility of the evaluation model.

2.1.2. Data preprocessing

We need to categorize the selected evaluation metrics that affect the player's condition evaluation score into two categories: very large metrics (larger values indicate good condition) and very small metrics (larger values indicate poor condition). And, the very small value indicators need to be processed positively. The specific processing method is shown in the table below (Take player 2 as an example, as shown in table 1):

Table 1. Indicator normalization for player 2.

	0	0.5	1
serve_no	2	/	1
point_victor	1	/	2
p2_ace	/	/	1
p2_winner	/	/	1
p2_double_fault	1	/	0
p2_unf_err	1	/	0
p2_net_pt	/	/	1
p2_break_pt	/	/	1
p2_distance_run	normalization process		
speed_mph	normalization process		
serve_width	B	BC/BW	C/W

Indicator normalization is a data processing method that converts values from different ranges into the same range. The data analysis in this question involves comparing and comprehensively evaluating data from different indicators, which often have different scales and magnitudes, and therefore require indicator normalization to facilitate comparison and processing. In this paper, we choose to use Min-Max normalization, in which the data is linearly transformed according to the prescribed minimum and maximum values and mapped to the interval from 0 to 1.

Among the indicators chosen in this paper, player 1's distance ran during, point (meters) player 2's distance ran during point (meters), which affects the player's state evaluation score, is a continuity indicator, which needs to be normalized, and the mathematical expression is as follows:

$$x_{norm} = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \tag{1}$$

2.2. Fuzzy Synthetic Evaluation Modeling

2.2.1. Description of the Fuzzy Synthetic Evaluation model

The Fuzzy Synthetic Evaluation is a method that utilizes fuzzy mathematical theories and methods to conduct comprehensive evaluation. Its core idea is to convert qualitative evaluation into quantitative evaluation in order to provide a comprehensive evaluation of objects or things that are affected by multiple factors. This method is able to deal with factors whose boundaries are unclear and not easily quantifiable, thus providing a clearer and more systematic evaluation result [5].

Generally speaking, the three basic elements of evaluation object, evaluation index and weight coefficient compose the comprehensive evaluation model.

1. Evaluation object

That is, the comprehensive evaluation model to output results of the object analyzed.

2. Evaluation indicators

Evaluation indicators are the basic elements that reflect the operation (or development) of the evaluation object. Usually the problem is composed of a number of indicators, each of which is a measure of the size of a certain feature from different sides of the portrayal of the system.

Generally, the vector x can be used to represent the evaluation index of a comprehensive evaluation problem, which is called the vector of evaluation index, of which each component is from a side to reflect the state of the system; also known as the comprehensive evaluation of the indicator system.

In establishing the evaluation index system, the following principles should be generally followed: 1 systematic; 2 independence; 3 observability; 4 scientific; 5 comparability. Without loss of generality, let the system have m evaluation indicators respectively noted as $x_1, x_2, ..., x_m (m > 1)$, i.e., the vector of evaluation indicators is $x = [x_1, x_2, ..., x_m]$.

The type introduction and pre-processing of the indicators are detailed

3. Weighting coefficient

Each comprehensive evaluation question has a corresponding evaluation purpose. When the evaluation purpose is different, the relative importance between the evaluation indexes is also different, and the weight coefficient can be described by the size of the relative importance between the evaluation indexes. If $w_j (j = 1, 2, .., m)$ is used to represent the weighting coefficient of the evaluation index x_j.

2.2.2. Determination of evaluation indicators

An indicator that a player is performing well:

Because a player who wins a point is in good shape for that match, the larger the $point_victor$ the higher the Ps.

Because hitting an untouchable winning serve means that the serve was so fast and from such a difficult angle that the opponent was unable to retrieve the point, the player is in good form, so the larger the p_i_ace is, the higher the Ps.

Because hitting a very good, almost untouchable winning shot means that the player is in good shape, the larger the p_i_winner is, the higher the Ps are.

Because tennis serve receive is generally outside the service line, absolute advantage in the case of the player will choose to go to the net to receive the ball, if the player has managed to approach the opponent's court, he will have a greater chance to attack the net or to make an interception, on behalf of the player is in good condition so the larger the $p_i_net_pt$ means the higher the Ps.

Because there is a chance to win the set on the opponent's serve, this means that the player is already ahead by a certain margin when the opponent serves, representing that the player is in good shape so a larger $p_i_break_pt$ means higher Ps.

Because the player in a point in the running distance data can be visualized to reflect the player in the game of the amount of movement, moving distance is large that the player's ability to move strong

and sufficient physical capacity, on behalf of the player in good condition, so the larger the $p_i_distance_run$ that the higher the P_S.

Because the faster the speed of the serve, the better the player's condition, so the larger the $speed_mph$ is, the higher the P_S.

Because the farther away from the opponent's location, so that the opponent is not easy to catch the ball, the player is more likely to score, representing the player's precise direction of control, good condition, so the larger the $serve_width$ means the higher Ps.

An indicator that the player is performing not very well:

Because one successful serve indicates that the player is in good shape for that game, the larger the $serve_no$ indicates the lower the Ps.

Because the serving side was in the advantageous side, when the serving side can't send the ball into the opponent's court or return error, or the opponent successfully breaks the serve, then the opponent wins the point, which indicates that the player is in bad condition, so the larger the $p_i_double_fault$ is, the lower the Ps is.

Because an unforced error means that the player will lose the point and will give the opponent the opportunity to win the point or the set. The error is not caused by the opponent's excellent performance or his own nervousness, but by his own technical errors or errors in judgment (usually including serve errors, return errors, errors at the net, etc.), which means that the player is in poor condition so the larger the $p_i_unf_err$ is, the lower the Ps is.

2.2.3. Entropy weighting method: determination of indicator weighting coefficients

When the evaluation object and the evaluation index value are determined, the value of the weight coefficient will determine the results of the comprehensive evaluation. This means that the rationality of the weight coefficients is directly related to the credibility of the evaluation results. The correctness of the final decision may also be affected. Therefore, the determination of weight coefficients should be particularly cautious and should be determined according to certain methods and principles. This paper adopts the entropy weight method [6-7].

In information theory, information entropy is a measure of information uncertainty. Usually, the amount of information is inversely proportional to the entropy value. A larger amount of information means a larger utility value of information. Entropy method is an assignment method that determines the weight coefficient of each index according to the relative change degree of each index to the whole system by calculating the information entropy of the observed values of each index. The calculation process of entropy method is as follows:

(1) Calculate the characteristic weight of the i^{th} rating object under the j^{th} indicator

Let the standardized data $b_{ij} > 0 (i = 1, 2, ..., n;\ j = 1, 2, .., m)$ of the j^{th} observation of the i^{th} rating object, then the characteristic weight of the i^{th} rating object under the j^{th} indicator is:

$$p_{ij} = \frac{b_{ij}}{\sum_{i=1}^{n} b_{ij}} (i = 1, 2, \cdots, n;\ j = 1, 2, \cdots, m) \tag{2}$$

(2) Calculate the entropy value of the j^{th} indicator as:

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} p_{ij} \ln p_{ij} (j = 1, 2, \cdots, m) \tag{3}$$

It is easy to see that if the difference between the observations of the j^{th} indicator is larger, the entropy value is smaller; conversely, the entropy value is larger.

(3) Calculate the coefficient of variation for indicator j as

$$g_j = 1 - e_j (j = 1, 2, \cdots, m) \tag{4}$$

If the difference in the observed values of the j^{th} indicator is greater, the coefficient of variation g_j is greater and the j^{th} indicator is more important.

(4) Determine the weighting factor for indicator j :

$$w_j = \frac{g_j}{\sum_{k=1}^{m} g_k} (j = 1, 2, \cdots, m) \tag{5}$$

The results were calculated: $serve_no$, $point_victor$, p_i_ace , p_i_winner , $p_i_net_pt$, $p_i_break_pt$, $serve_width$, $p_i_distance_run$, $speed_mph$'s weights were 0.152, 0.124, 0.008, 0.036, 0.003, 0.028, 0.027, 0.007, 0.229, 0.164, and 0.221 respectively, as shown in figure 1. Among them, the error on both serves accounted for the smallest percentage, presumably because the probability of the error on both free throws being present in a large tournament such as Wimbledon is very small, so it has less impact on the final score in the reflection of the analyzed results.

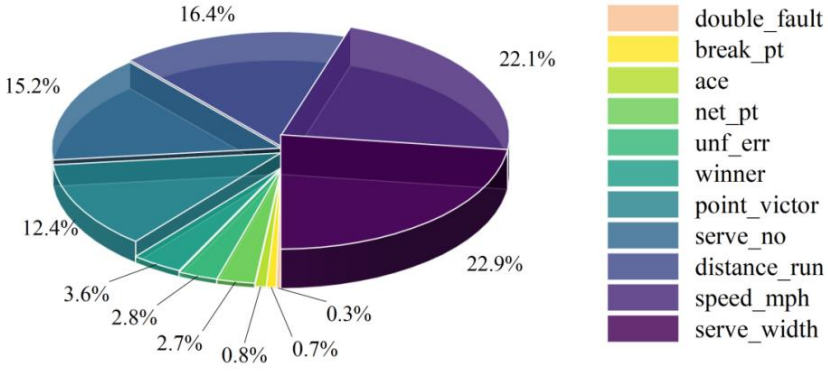


Figure 1. Pie chart of indicator weights.

2.3. Wavelet Analysis Model

Wavelet transform (WT) is a powerful tool for signal analysis, which was proposed by Morlet in the late 1980s in the analysis of geophysical signals, and it is the crystallization of the intersection of many disciplines such as generalized function analysis, Fourier analysis, spline theory, numerical analysis, and so on, and it is a powerful tool to analyze the non-smooth signals, which can analyze the signal's generalization It can also analyze the details of the signal. In the field of image denoising, many excellent properties of wavelet transform make it widely used [8].

The basic idea of wavelet domain denoising is to decompose the signal into low frequency and high frequency signals through wavelet transform. The high-frequency components relate noise and disturbance, and the signal features are derived using the low-frequency components. Subsequently, the high-frequency components of the signal are removed. In this way, not only the basic characteristics of the signal can be preserved, but also the noise in the data can be removed.

In signal processing, noise can be classified as additive noise and multiplicative noise. Additive noise is the longest encountered. According to this feature, we classify the noise generated by data excess as n class noise. The establishment of the score of the signal noise-containing model as:

$$y_i = x_i + Cn_i \quad (i = 1, 2, 3.....n) \tag{6}$$

Where n_i is the zero-mean Gaussian White Noise (White Gaussian Noise), y_i is the noise-containing signal, the useful signal to be extracted, and C is the noise variance. The problem of filtering the noise n_i can be considered as how to recover the expected value x_i from the observation y_i.

According to the above model, this paper utilizes the PyWavelets library in Python to perform one-dimensional noise reduction processing of gene information. The main processing can be divided into three parts:

Step 1: Signal decomposition: choose the wavelet basis function and the level N of decomposition, and calculate the wavelet decomposition coefficients of each level.

Step 2: Thresholding the wavelet detail coefficients: for each layer from 1 to N, select the thresholds respectively, and filter the thresholds by soft thresholding or hard thresholding.

Step 3: Signal reconstruction: the signal is reconstructed using the approximate value coefficients of the nth layer and the threshold-filtered detail coefficients of the layers from 1 to N. The resulting reconstructed signal is the signal after noise reduction.

2.4. Analysis of results

2.4.1. For "How well did the players perform"

This question takes the remarkable battle mentioned in the question stem-the final of Wimbledon 2023 as an example to show the result of model analysis, aiming to analyze the various details of the remarkable battle with you, such as the fluctuation of the performance of both and the reasons for the failure of the senior.Carlos Alcaraz's values in each point of the match is shown in figure 2.

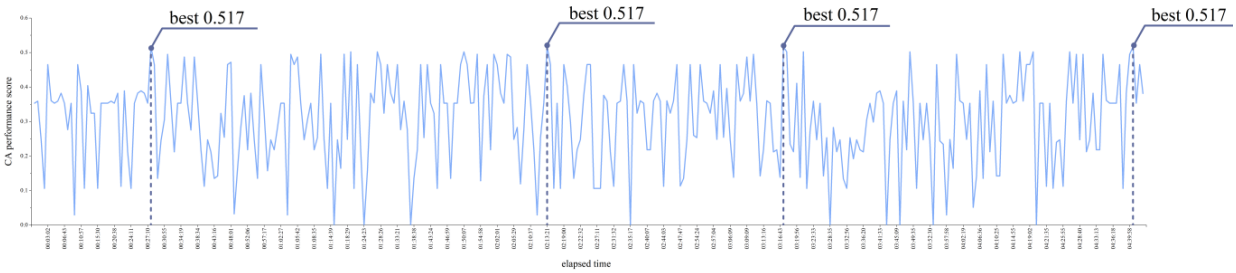


Figure 2. Carlos Alcaraz's P_s values in each point of the match.

By modeling this question, it is possible to make a score for Carlos Alcaraz's performance in each round of the fight. Visualize this time series as shown in Figure X. As shown in the figure, Carlos Alcaraz was at his best at 00:28:47, 02:13:21, 03:17:19, and 04:40:43 after the start of the fight. Described by Performance score, Carlos Alcaraz scored 0.517 at these time points [9-10].

At 00:28:47 in the 6th game of the 1st set of the match, in the 36th round of the match, it was Carlos Alcaraz's turn to serve. At this point Carlos Alcaraz had already lost five games in a row (according to the rules of the match, if he lost one more game, the set was lost). Perhaps this is why he adjusted his form. In this set, he managed to score points in several consecutive rounds. Carlos Alcaraz even hit an untouchable winning serve (forehand) in this set. He also came to the net during the match. That's a good sign that he was in good shape during the round. Finished the round with only three shots. The direction of the serve is also well controlled, directly towards the center of the court. This puts more pressure on the opponent, who has to move and return the ball over a larger area. He runs around 9 meters in this game. Although this is less than Novak Djokovic's 12m, it is not a big difference. This also shows that Carlos Alcaraz is in control of the round.

At 02:13:21 in the 3rd game of the 3rd set of the match, in the 154th over of the match. It was Carlos Alcaraz's turn to serve. Carlos Alcaraz had just won a set in his winning streak. Carlos Alcaraz just won a set in a winning streak. In this round, Carlos Alcaraz hit a winner. Serving at 126. He served in the direction of his opponent's body and still won the point. He was in good shape.

At 03:17:19, in the 3rd game of the 4th set, in the 226th round of the match, Carlos Alcaraz was serving. It was Carlos Alcaraz's turn to serve, who had already won two sets and was ahead of his opponent. The serve is going well. The direction of the serve was well controlled and it was directed towards the center of the court. He also hit an untouchable winning serve (backhand) during the match. Eventually took full control of the game and came to the net to win the point.

At 04:40:43 it is the 10th game of the 5th and final set of the match. It is Carlos Alcaraz's turn to serve. According to the description of the question and the video replay of the match, Novak Djokovic led the first four games by four games to one before Carlos Alcaraz ended the match by 6:4. Carlos Alcaraz was destined to win this match. Carlos Alcaraz was destined to win the match. He controlled both the direction of his serves and his errors very well. He hit an untouchable winning serve (backhand) in the middle of the set. Finally he came to the net to take the point. Novak Djokovic's P_s values in each point of the match is shown in figure 3.

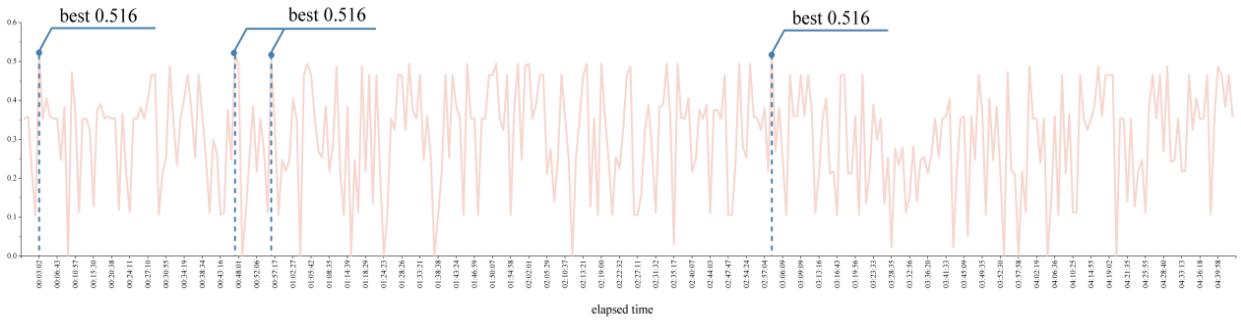


Figure 3. Novak Djokovic's P_s values in each point of the match.

Novak Djokovic was at his best at 00:03:02, 00:47:10, 00:56:40, and 02:58:04 after the start of the race. Using the Performance score, Novak Djokovic scored 0.517 at these points.

At 00:03:02, in the first game of the first set, in the fifth round of the match, it was Novak Djokovic's turn to serve. It was Novak Djokovic's turn to serve, and Novak Djokovic had suffered two previous sets in which he had not succeeded on his first serve. From this game he adjusted his condition. He got his serve back. Serves a sharp serve and serves to the net. Won the point after one round of shots. It shows that Novak Djokovic is in good shape at this time.

At 00:47:10 in the second game of the second set, in the 59th round of the match, it was Novak Djokovic's turn to serve, and Novak Djokovic started the match with a good serve. Novak Djokovic was already ahead of Carlos Alcaraz. But Carlos Alcaraz scores in the first two games. Novak Djokovic adjusted and won a game to start the round. Novak Djokovic created an opportunity to get to the net in a match where both players moved more than 30 meters. Unfortunately, Novak Djokovic was unable to get the scoreboard going in this round.

At 00:56:40 in the 4th game of the 2nd set of the match, in the 69th round of the match. It is Novak Djokovic's turn to serve. Novak Djokovic has turned the tables on his opponent, who was serving in the previous game, and lost the set. In the new set, Novak Djokovic took advantage of his serve and started the game with a good and tricky serve. Keeping his winning streak alive. Takes advantage of his opponent's errors. Won the set in 4 games.

At 02:58:04 in the 7th game of the 3rd set of the match. It was Novak Djokovic's turn to serve. At this point, there was a slight reversal in their scoring (i.e. from Novak Djokovic having the upper hand to both players scoring similarly). After his opponent won a couple of rounds due to his own errors, Novak Djokovic adjusted his game. Sharp serve. In a back and forth, he won the match point.

2.4.2. For "Which player performs better at a given time of the game"

When comparing and analyzing the performance of the two at a specific time, it is inevitable to be affected by too much data, resulting in a lot of noise interfering with the analysis in the image. After analyzing the advantages and disadvantages of various noise reduction methods. To reduce the noise of both data, we choose to use wavelet transform. The denoised images are then used to analyze and compare the performance of the two algorithms at different time instants.

The resultant graph after noise reduction using wavelet analysis model is shown in figure 4 and 5:

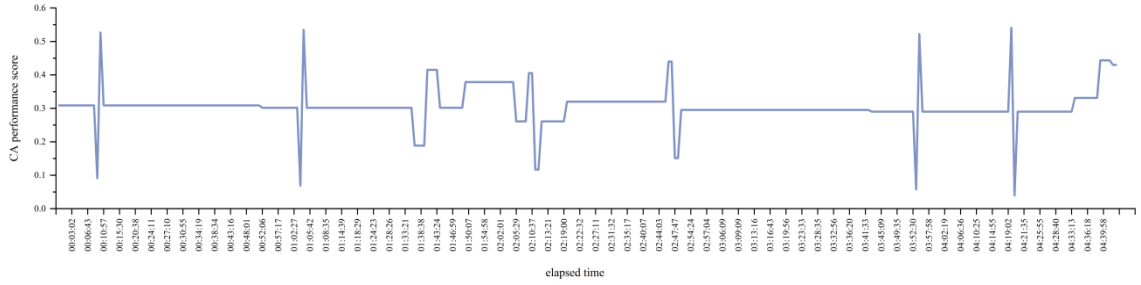


Figure 4. Plot of Carlos Alcaraz score over time after noise reduction.

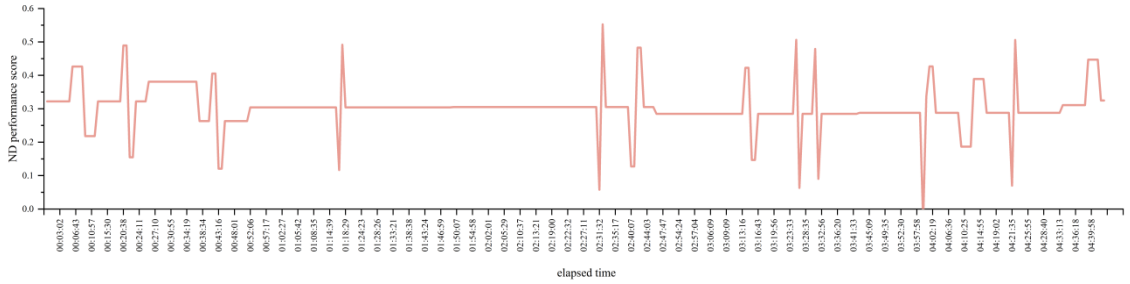


Figure 5. Graph of Novak Djokovic's score over time after noise reduction.

Comparison of the two graphs shows that Novak Djokovic scored higher in the first set and had a significant advantage over Carlos Alcaraz. The senior won easily. In the second set, the senior's scores dipped and the junior's scores rose. The junior was slightly better. In the third set, the junior's performance score is significantly higher, and the senior is not as good. The junior won easily. The fourth set saw a slight increase in the veteran's score and a slight decline in the junior's. The veteran won narrowly. Veteran wins narrowly. In the fifth set, the veteran started to lead, and the junior overtook him in the middle and late stages of the match. In the end, the junior won by a wide margin over the senior.

From this, we can see that the senior may have performed very well in the early part of the match due to his rich experience. However, the senior may lack stamina and smoothness due to age or mental quality. On the other hand, although the junior general's performance in the early stage is inferior, his stamina is superb. And withstand the psychological pressure of failure in the middle of the game, continue to play steadily. He was able to keep the momentum until the end and finally won the championship.

3. Conclusions

Through the comprehensive assessment and analysis of the players' performance in the competition, we have come to the following conclusions:

Firstly, the performance of players is affected by various factors, including technical level, psychological quality, physical condition and game strategy. These factors are intertwined with each other and together determine the overall performance level of a player in a match. Secondly, scientific evaluation methods and signal processing technology provide important support for us to understand the characteristics of players' performance and the change rule. The fuzzy comprehensive evaluation model can objectively reflect the overall state of the players. The weights of key indicators are determined by means of the information entropy weighting method. The noise in the data is effectively eliminated by the wavelet evaluation model. It enables us to observe and analyze the performance data of the players more accurately. Finally, in-depth assessment and analysis of players' performance is of great significance to the improvement of sports competitions. By scientifically understanding and evaluating the performance characteristics of athletes in the competition, not only the training and competition of athletes can be guided more accurately, but also the progress of athletes and the improvement of competition results can be achieved.

Therefore, to improve the competitive level of athletes and optimize the performance of the competition, this study has certain practical significance and application value. At the same time, the evaluation methods and analysis techniques adopted in this study also provide some reference and reference for future research in related fields.

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