Research On Momentum Evaluation in Tennis Competitions Based on Entropy Weight Method and TOPSIS Method

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Abstract. In competitive sports, assessing an athlete's momentum on the field is essential to develop a training plan and improve the competitiveness. In order to establish a comprehensive evaluation system to comprehensively evaluate the momentum of athletes in tennis competitions, this paper designed a system containing 15 evaluation indicators, covering skills, mentality and physical fitness, and used the entropy weight method to determine the index weights, and then used the TOPSIS method to calculate the momentum scores. The specific weight of each indicator in the evaluation system and the athlete's momentum score at each point in the competition were obtained. By analyzing the score changes, the stability of the athlete's performance and the trends of winning and losing in the competition are revealed. The method of this paper provides a scientific framework for evaluating the momentum of athletes in tennis competitions, which helps to understand the strengths and improvement of athletes in the game more comprehensively, and provides theoretical support and guidance for improving training plan and competitiveness.

Keywords: Entropy weighting method, TOPSIS method, Momentum assessment.

1. Introduction

In the 2023 Wimbledon Gentlemen's singles final, Novak Djokovic suffered his first Wimbledon defeat since 2013. One of the all-time Grand Slam greats' runs was broken by 20-year-old Spanish tennis player Carlos Alcaraz.

The whole game was controlled by the two sides many times, and sometimes during a player's many consecutive scores or multiple games, there were many incredible swings from the seemingly dominant player. In sports, a team or a player in the course of a game often has a similar incredible performance, which is summed up as "momentum," which is defined in the dictionary as "strength or power acquired through movement or a series of events." Because of the influence of momentum generation on the game and the difficulty of its measurement, how to generate and control momentum in the sports arena is particularly important and difficult [1].

In order to establish a comprehensive evaluation system to comprehensively evaluate the performance of athletes in tennis matches [2], this paper firstly preprocesses the data by using Pearson correlation coefficient and K-means clustering method and then establishes kinetic energy evaluation system by using mentality, physical [3] fitness and skill, and uses entropy weight method and TOPSIS to evaluate players' performance [4].

2. Construction of momentum evaluation system based on entropy weight-TOPSIS

2.1. Construct evaluation index system

In the process of a match, the performance of athletes will be affected by many aspects such as skills, mentality [5] and physical quality. This paper selects evaluation indicators based on previous research of scholars and ATP website [6].

Firstly, for the skill index of the player, this paper selects the player's score and whether he can successfully send or return the non-touch serve to evaluate [7]. A total of five indicators, including the success of the previous point, the leading of the match, whether the serve score, whether the return score, the opponent served the chance to score and the actual score ratio. The formula for calculating the scores in the match score is shown in (1).

$$y_i = \sum_{i=1}^{j} x_{1,i} - \sum_{i=1}^{j} x_{2,i} (j = 1,2,\cdots,n) \tag{1}$$

Where n represents the number of games played in the current match, $x_{1,i}$ and $x_{2,i}$ represents the score of each player.

As for the reaction index of players' mentality, this paper selects the players' error performance and whether they have a service advantage for consideration, while the players' physical fitness is reflected by selecting the players' running mileage and real-time service pace in the match [8]. Therefore, the index system reflecting the performance of players on the tennis court is shown in Figure 1 below, including 15 evaluation indicators.

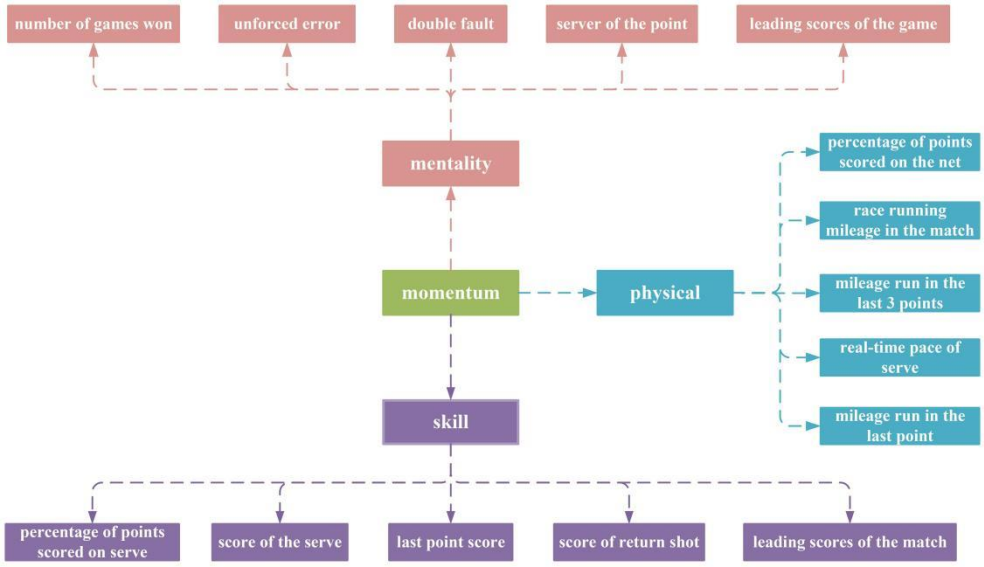

Figure 1 Structure chart of evaluation index system

2.2. Establish momentum model based on entropy weight - TOPSIS method

2.2.1 Select the weight coefficient of evaluation index

Since entropy weight method can objectively reflect the degree of differentiation between the selected indexes and the evaluation objects, the smaller the difference in the performance indexes of the players, the smaller the impact on the momentum change of the players in the whole match. Therefore, this paper selects entropy weight method to determine the weight of the evaluation indicators.

Firstly, based on the evaluation system, the index level matrix $R^{'}$ is constructed and standardized to obtain $R=(r_{i,j})_{m*n}$. The results of the corresponding evaluation matrix R for player p1 are shown in the following Table 1.

Table.1. The evaluation matrix of player p1

Point	x_1	x_2	x_3	x_4	x_5	…	x_{13}	x_{14}	x_{15}
1	0.1667	0.3125	1	0	0.6667	…	0.3032	0.5	0.8088
2	0.1667	0.6875	1	1	0.6667	…	0.0826	0.5538	0.8235
3	0.1667	0.5	1	1	0.6667	…	0.2582	0.8269	0.9338
…	…	…	…	…		…	…	…	…
299	0.5	0.875	1	1	0.6667	…	0.0896	0.5962	0.8456
300	0.5	0.8125	0	1	0.6667	…	0.4529	0.3269	0

x_1 is the number of games won, x_2 is the unforced error, x_3 is the number of double fault, x_4 is the number of server of the point, x_5 is the leading scores of the game, x_6 is the percentage of points scored on the net, x_7 is the race running mileage in the match, x_8 is the mileage run in the last 3 points, x_9 is the real-time pace of serve, x_{10} is the mileage run in the last point, x_{11} is the leading scores of the match, x_{12} is the score of return shot, x_{13} is the last point score, x_{14} is the score of the serve and x_{15} is the percentage of points scored on serve [9].

Then, this paper will calculate the specific gravity p_{ij} corresponding to the i index and the entropy weight w_j corresponding to the j index [10].

$$p_{ij}=\frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}} \tag{2}$$

$$w_i=\frac{1+k\sum_{i=1}^{m} p_{ij}}{\sum_{j=1}^{n} 1+k\sum_{i=1}^{m} p_{ij}}, k=\frac{1}{\ln m} \tag{3}$$

The above method can be used to obtain the weight results of each index corresponding to player p1, as shown in Table 2.

Table.2. Table of results for each index weight

x_1	x_2	x_3	x_4	x_5
6.1662	1.0593	5.1935	4.3441	0.4422
x_6	x_7	x_8	x_9	x_{10}
42.4723	24.5088	0.0037	1.6705	2.7682
x_{11}	x_{12}	x_{13}	x_{14}	x_{15}
2.9304	1.5912	0.5372	1.0841	5.2342

2.2.2 Determine the momentum score based on TOPSIS

Since the player's performance is closer to the optimal performance, it can reflect its current momentum corresponding to greater. Therefore, this paper uses TOPSIS method to calculate the distance between the optimal state and the worst state of the player's current performance, and then obtains the momentum score corresponding to the player at different scoring points.

Firstly, the weight W_i obtained by entropy weight method and the evaluation matrix R corresponding to player p1 are used to obtain the corresponding weight norm X (as shown in the formula (4)).

$$X_{ij}=W_j \bullet R_{ij} \tag{4}$$

The corresponding results of the weighted norm score matrix are shown in the following Table 3.

Table.3. The weighted normative scoring matrix

Point	x_1	x_2	x_3	x_4	x_5	...	x_{13}	x_{14}	x_{15}
1	0.0048	0.0034	0.0277	0	0.0349	...	0.0064	0.0079	0.0042
2	0.0048	0.0091	0.0277	0.0349	0.0349	...	0.0076	0.0088	0.0045
3	0.0048	0.0074	0.0277	0.0349	0.0349	...	0.0013	0.0097	0.0057
...	...	...	...	...		...	...	...	...
299	0.0147	0.0158	0.0277	0.0349	0.0349	...	0.0009	0.0088	0.0045
300	0.0147	0.0091	0	0.0349	0.0349	...	0.0007	0.0054	0

Next, confirm the positive ideal solution and negative ideal solution of players' performance. The positive ideal solution can reflect the optimal state of skills, mentality and physical quality that player 1 may achieve in their overall performance on the court, while the negative ideal solution reflects the worst performance of players caused by mistakes and physical exertion during the game (as shown in the Table 4).

Table.4. Positive and negative ideal solutions

	x_1	x_2	x_3	x_4	...	x_{14}	x_{15}
Positive ideal solution	0.0294	0.0316	1	0	...	0.0079	0.0042
Negative ideal solution	0.0048	0.0034	0	0.0349	...	0.0088	0

The distance between the player's real performance and the positive and negative ideal solution at each point is calculated (as shown in formula (5) and formula (6)).

$$d_i^* = \sqrt{\sum_{j=1}^{n} (x_{ij} - x_j^*)^2} \tag{5}$$

$$d_i^0 = \sqrt{\sum_{j=1}^{n} (x_{ij} - x_j^0)^2} \tag{6}$$

Where x_j^* represents the evaluation index vector corresponding to the positive ideal solution, x_j^0 represents the negative ideal solution, d_i^* represents the distance between the real performance and the positive ideal solution, d_i^0 represents the distance between the real performance and the negative ideal solution. The distance between the performance of each point of p1 player in the first round match and the positive and negative ideal solution is shown in the following Table 5.

Table.5. Distance from positive and negative ideal solutions

Point	Positive ideal solution	Negative ideal solution
1	0.9436	0.2661
2	0.9004	0.3715
3	0.8839	0.4087
4	0.7527	0.6253
5	0.3116	0.9207
...	...	...
299	0.8749	0.4276
300	0.8642	0.4321

Finally, Formula (7) is used to obtain the comprehensive score corresponding to each point in the tennis match, namely momentum.

$$C_i^* = \frac{d_i^0}{(d_i^0 + d_i^*)} \tag{7}$$

In the first match, for example, the momentum changes of p1 players at each scoring point are shown in Figure 2.

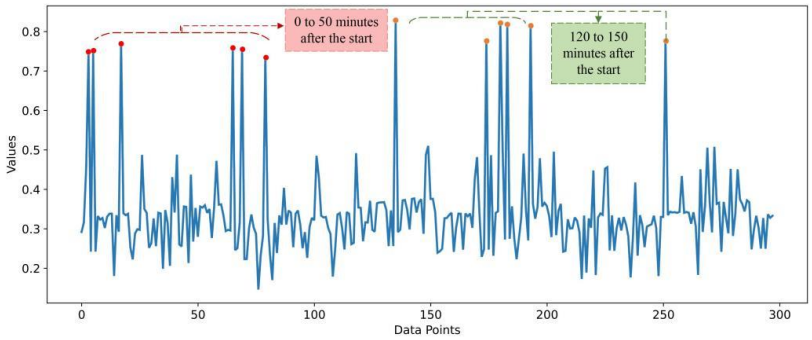

Figure. 2 Plot of the momentum change of p1

3. Conclusions

This article is based on the match data of the players from both sides in the 2023 Wimbledon tennis final. In order to identify which player performed better at a specific time during the match, we aim to develop a comprehensive evaluation model that can be applied to tennis events or other individual competitions. By using the entropy weight method to determine indicator weights and the TOPSIS method to calculate momentum scores, the specific weights of 15 indicators in three categories of skills, mentality, and physical fitness were obtained in the evaluation system, as well as the momentum scores of athletes at various time points in the competition. Selecting the first round of the game and applying the model to Player 1, it was found that they were in a moderately stable fluctuation state at each scoring point. However, there was a significant increase in momentum in the 0-50 minutes and 120-150 minutes of the game, accompanied by multiple consecutive occurrences of high momentum in the game. Analyzing the changes can reveal the stability and trend of the athlete more comprehensively and scientifically, which helps to comprehensively improve the athlete's advantage and improvement space in the competition and provides theoretical support for training and competition.

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