Chen *et al.*
*BMC Sports Science, Medicine and Rehabilitation* (2025) 17:45
https://doi.org/10.1186/s13102-025-01092-8

BMC Sports Science, Medicine and Rehabilitation

RESEARCH

Open Access

# Evaluation of elite table tennis players' comprehensive technical and tactical performance

Zhihao Chen[1], Muzi Li[1] and Qing Yang[1*]

**Abstract**

**Background** Game performance analysis has been playing a significant role in sports events which has reached an international consensus. In the field of technical and tactical analysis of table tennis, many studies conducted the segmented evaluation of players based on the phased-theory. The present study proposed the concepts of "competitive technical and tactical performance" of elite table tennis players. The purpose of this study was to develop an entropy-based weighting system integrated with three comprehensive evaluation methods, aiming to examine its feasibility for evaluation in two practical applications: inter-athlete comparison and performance fluctuations across time periods. Another purpose was to explore the applicability of different comprehensive evaluation methods through comparative application.

**Methods** A total of 40 matches of six elite male table tennis players in 2019 were selected to evaluate their competitive technical and tactical performance. The technical effectiveness of four phases in a match as the relevant indexes, three comprehensive evaluation methods, including the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method, the Rank-sum ratio method and the Osculating value method were applied based on the Entropy weight method. Kendall's concordance coefficient and Spearman's correlation coefficient were employed to examine the consistency and correlation.

**Results** (1) The technical strength ranking of the six elite table tennis players was as follows: Player A, Player B, Player C, Player F, Player E, and Player D. This ranking exhibited a high degree of consistency with the international rankings as of December 2019. Notably, Player C's performance showed significant fluctuations, whereas Player E demonstrated a steady and upward performance trend. (2) All Kendall's concordance coefficients exceeded 0.948, and all Spearman's correlation coefficients were above 0.883, with statistically highly significant results ($p < 0.01$).

**Conclusions** All three comprehensive methods were shown to have strong applicability and high consistency in evaluating the comprehensive performance of athletes. The TOPSIS method performed more well. This approach facilitated a more in-depth and comprehensive representation of table tennis match analysis, providing practical applications for athletes and coaches.

*Correspondence:
Qing Yang
qyang@suda.edu.cn

**Key points**

- The present study proposes the concepts of "competitive technical and tactical performance" of excellent table tennis players. It will help for a more in-depth analysis the athlete's technical performance.
- The Entropy-based TOPSIS method, the RSR method and the Osculating value method was applied to evaluate the players' competitive technical and tactical performance. The suitability of the three comprehensive evaluation methods was compared in the actual evaluation.
- The comprehensive evaluation method could help for evaluating the competitive technical and tactical performance of athletes, which can not only accurately evaluate the competitive performance of multiple athletes at the same stage, but also longitudinally evaluate the competitive performance of an athlete in different time periods.

**Keywords** Ping-pong ball, Comprehensive assessment, TOPSIS, RSR, Osculating value method, Game performance

## Background

Game performance analysis plays a significant role in sports events which has reached an international consensus [1–4], and in a match, technical and tactical performance is critical to the outcome in confrontational sports [5], because the technique and tactics are key factors in athletes' competitive abilities, according to sports training theory and practice [6]. Research on technical and tactical performance has been a subject of global concern [7–9].

### Evaluation of technical and tactical performance

In the technical and tactical analysis of table tennis, the evaluation of performance has always been a core part of scientific research in this sport. As early as the 1980s, Wu [10] proposed the "three-phase evaluation theory", in which a match would be divided into three phases: the serving and attacking phase, receiving and attacking phase and rallying phase. This theory was widely used to prepare for major international competitions by the Chinese table tennis team and received high praise from coaches and athletes. Many researchers have made some improvements on this basis in recent years. For example, the modifying method of studying table tennis technique and tactics [11], the "four-phase evaluation theory" [12], the expanded application of "three-phase evaluation" [13], a phased model for table tennis chopping stroke [14], dynamic three-phase method [9], double three-phase method [15]. Many related studies have applied these proposed phased methods to analyze the specific games or players [14–16]. All the above methods can be called "phased evaluation theory", which combines several shots into different phases in a match to evaluate a player's technical and tactical performance. Therefore, the assessment of these methods is a phased evaluation, according to which, the result is the athletes' segmented technical and tactical performance.

Although more accurate scientific explorations of evaluation indicators (e.g., usage rate and scoring rate) have been undertaken—such as Zhang et al.'s proposal of the concept of technical effectiveness [17], Tamaki et al.'s introduction of shot effectiveness [18], and even Yang et al.'s exploration of the structure of the shot effectiveness model [19]—the substance has not changed and remains a segmented evaluation. The problem with segmented evaluation was that it was difficult to assess an athlete's performance as a whole. For example, if Player X is rated as "excellent" in one phase, "poor" in another, and "general" in a third, while Player Y is rated as "general" in all phases, it will be difficult to compare their overall performance. Therefore, this study proposed a concept of "comprehensive technical and tactical performance" and tried to apply evaluation methods to assess it. In practice, people often use match results to evaluate the comprehensive performance of athletes. For example, a score of 0:4 typically indicates poor performance by the athlete and a significant gap compared to the opponent, while a score of 4:3 suggests a hard-fought victory. However, this approach only provides a vague assessment of the athlete's overall performance based on the scoreline and fails to enable direct comparisons among multiple athletes.

### Comprehensive evaluation methods

When dealing with complex scenarios where the evaluation object is simultaneously influenced by multiple factors, it is necessary to integrate multiple factors (indicators) to rank and evaluate the object in terms of its relative merits. This approach was referred to as the comprehensive evaluation method, also known as the multivariate comprehensive evaluation method. It was a technique applied to quantitatively evaluate and compare multiple indicators and populations simultaneously [20]. Currently, the commonly used comprehensive evaluation methods include the Technique for Order Preference by

Similarity to an Ideal Solution (TOPSIS) method [21], Rank-sum ratio (RSR) method [22], Osculating value method [21]. The above comprehensive evaluation methods have been widely and diversely applied in sports. The TOPSIS method was applied to football [23, 24], basketball [25–27], table tennis [28, 29], and also applied in areas such as match result prediction [30] and financial efficiency [31], providing important references for decision-makers. The RSR method has also been applied in basketball [32–34], volleyball [35–37], and football [38]. The Osculating value method was mainly applied in basketball [39, 40], it has been widely applied in fields healthcare quality evaluation [41, 42], and technological innovation capacity evaluation in industry [43, 44] due to its quick and easy-to-understand.

However, in previous studies, the evaluation process had typically relied on a single method and paid less attention to the weighting of indicators. Due to the different principles of comprehensive evaluation methods, each had its own advantages and disadvantages in the actual evaluation situation, and relevant studies show that there were inconsistencies between the different comprehensive evaluation methods [45, 46]. Therefore, this study introduced the entropy weight method to determine the weights of various technical and tactical performance indicators. The TOPSIS method, RSR method, and Osculating value method were employed for comprehensive evaluation and comparison.

The present study proposed the concepts of "competitive technical and tactical performance" of excellent table tennis players. One purpose of this study was to develop an entropy-based weighting system integrated with three comprehensive evaluation methods, aiming to explore its feasibility for evaluation in two practical applications: inter-athlete comparison and performance fluctuations across time periods. By independently evaluating these two dimensions, this approach facilitated the comparison of comprehensive technical and tactical performance among multiple athletes within the same timeframe, while also enabling the analysis of performance fluctuations in individual athletes over a specified period. Ultimately, this methodology allows for the quantification of an athlete's competitive technical and tactical performance in matches as a precise numerical value. Thus, it eliminates the need for vague judgments based solely on match results (e.g., 0:4, 4:3) or fragmented evaluations based only on phased theory. Another purpose was to explore the applicability of different comprehensive evaluation methods through comparative application. The following hypotheses are proposed: (a) the combination of three entropy-based weights with comprehensive evaluation methods will improve the assessment of athletes' comprehensive performance. Both the comparison of different athletes and the evaluation across different time periods can demonstrate high feasibility in practice. (b) the results of the three comprehensive evaluation methods for assessing an athlete's technical and tactical performance will vary, with the TOPSIS method likely outperforming the others.

## Methods

### Design

This study employed three entropy-based weights combined with comprehensive evaluation methods (the TOPSIS, RSR, and Osculating method) to assess the technical and tactical performance of elite table tennis players. The evaluation comprised two parts: Part 1 was a cross-sectional study comparing the competitive performance of six players, while Part 2 was a longitudinal study examining performance variations of a single player across different time periods, using Player C and Player E as case studies. In Part 3, a comparison of the three comprehensive methods were conducted.

### Match samples

This study analyzed 36 matches of six elite male table tennis players in 2019 to evaluate their competitive technical and tactical performance (Result Part 1), with each player participating in 6 matches. Furthermore, 3 additional matches for Player C and 1 additional match for Player E were included to examine performance variations across different time periods (Result Part 2). These players were all among the top 12 in the world rankings (based on the International Table Tennis Federation rankings in December 2019). All matches were internationally renowned tournaments, including the World Cup, World Championships, Asian Cup, and ITTF Open tournaments. The opponents in these matches were evenly matched, with their world rankings all within the top 18. All match videos were sourced from television broadcasts and public website, as the ITTF website (https://www.ittf.com/), WTT website (https://worldtabletennis.com/) and ATTU website (https://asia.ittf.com/). Therefore, written ethical approval was not required.

### Procedures

#### *Data observation and collection*

The observation method and codes of table tennis match are illustrated in Table 1 [12]. At first, the status of scored or lost by the target player at the last shot in each point are observed, and then the last shot number and the number of points scored and lost by the player in the match.

After testing by SPSS, the data in this study showed no missing values or outliers. Two table tennis players were recruited to collect data and test inter- and inter-observer reliability [1]. Both randomly selected and independently observed and recorded data from 5 matches. After testing by Cohen's Kappa, and the result was $k=1$, indicating good consistency and suitability for research purposes.

**Table 1** Observation method and codes of table tennis match

| Round | Shot | Scoring | Losing | Total |
|---|---|---|---|---|
| Serving round | #1 | Lost in #2 of opponent (A+) | Lost in #1 of target player (A-) | A |
| | #3 | Lost in #4 of opponent (B+) | Lost in #3 of target player (B-) | B |
| | #5 | Lost in #6 of opponent (C+) | Lost in #5 of target player+ | C |
| | #≥7 | Lost in #≥8 of opponent (D+) | Lost in #≥7 of target player (D-) | D |
| Receiving round | #2 | Lost in #3 of opponent (X+) | Lost in #2 of target player (X-) | X |
| | #4 | Lost in #5 of opponent (Y+) | Lost in #4 of target player (Y-) | Y |
| | #≥6 | Lost in #≥7 of opponent (Z+) | Lost in #≥6 of target player (Z-) | Z |

***Relevant indexes***

The phased evaluation method has been widely applied in the research of table tennis tactics. Among them, the "four-phase evaluation theory" has received recognition from coaches and athletes in practice [47]. Meanwhile, it has also been well applied in scientific research [48–50], and has been referenced in similar group projects [51, 52]. In this study, the technical effectiveness ($TE$) [17] was applied to construct "four-phase $TE$", including technical effectiveness in the serving and attacking phase ($TE_1$), technical effectiveness in the receiving and attacking phase ($TE_2$), technical effectiveness in the serving and rallying phase ($TE_3$), and technical effectiveness in the receiving and rallying phase ($TE_4$).

Let $x$ represents the scoring rate and $y$ represents the usage rate. The calculation formula for $TE$ of a certain indicator is as follows:

$$\boldsymbol{TE = -\left(1+\frac{\sqrt{2}}{2}\right) + \left(1.5+\sqrt{2}\right)\left[(1+y)^{x-0.5}\right] - \frac{\sqrt{2}}{2}\left[(1+y)^{2(x-0.5)}\right]} \quad (1)$$

Let $I$ represent the sum of total points scored and lost in a match, $I=A+B+C+D+X+Y+Z$. The calculation methods for scoring rate and usage rate are as follows:

$$\text{Scoring rate of serving and attacking phase}(x1) = \frac{A^+B^+}{A+B+C^-} \times 100\% \quad (2)$$

$$\text{Usage rate of serving and attacking phase}\left(y1\right) = \frac{A+B+C^-}{A+B+C+D} \times 100\% \quad (3)$$

$$\text{Scoring rate of receiving and attacking phase}(x2) = \frac{X^+ + Y^+}{X+Y} \times 100\% \quad (4)$$

$$\text{Usage rate of receiving and attacking phase}\left(y2\right) = \frac{X+Y}{X+Y+Z} \times 100\% \quad (5)$$

$$\text{Scoring rate of rallying phase I }(x3) = \frac{C^+ + D^+}{C^+ + D} \times 100\% \quad (6)$$

$$\text{Usage rate of rallying phase I }\left(y3\right) = \frac{C^+ + D}{A+B+C+D} \times 100\% \quad (7)$$

$$\text{Scoring rate of rallying phase II }(x4) = \frac{Z^+}{Z} \times 100\% \quad (8)$$

$$\text{Usage rate of rallying phase II }\left(y4\right) = \frac{Z}{X+Y+Z} \times 100\% \quad (9)$$

By Formulas (1, 2, 3, 4, 5, 6, 7, 8 and 9), the relevant indexes can be obtained, which include $TE_1$, $TE_2$, $TE_3$, and $TE_4$.

***Entropy weight method***

The entropy weight method is an objective weighting method that determines the weights of indicators based on the entropy of the indicators. It considers the relative degree of change of the indicators and their impact on the overall system. The greater the relative degree of change, the smaller the entropy, and the higher the weight. Conversely, the smaller the relative degree of change, the larger the entropy, and the lower the weight [53, 54].

(1) Establishing an original indicator matrix $A$ with the number of evaluation objects is m and the number of evaluation indicators is $n$, then, $A=(a_{ij})_{m\times n}$ $(i=1, 2, \ldots, m; j=1, 2, \ldots, n)$

(2) Matrix normalization. Evaluation indicators are often classified as high- and low-performing indicators, where higher values are considered more favorable for high-performance indicators, while low-performance indicators are the opposite. All the technical indices in the "four-phase evaluation model" are high-performance. The range normalization formula was used to process the indicators and then got a normalized matrix $R=(r_{ij})_{m\times n}$, $r_{ij}\in[0, 1]$.

$$r_{ij}=\frac{a_{ij}\text{-}\min(a_{ij})}{\max(a_{ij})\text{-}\min(a_{ij})} \quad (10)$$

(3) Calculating information entropy. For $m$ evaluation objects and $n$ evaluation indicators, the information entropy of the $j_{th}$ evaluation indicator is calculated as:

$$H_j=-k\sum_{i=1}^{m} f_{ij}\ln f_{ij} \quad (11)$$

where $f_{ij}=r_{ij} / \sum_{i=1}^{m} r_{ij}$; $k=1/lnm$; and it is set that $f_{ij}ln f_{ij}=0$, when $f_{ij}=0$.

(4) Determining weights. The entropy weight $w_j$ of the $j_{th}$ indicator is calculated as:

$$Wj=\frac{1Hj}{\sum(1Hj)},\ j=1,\ 2,\ \ldots,n \quad (12)$$

## Comprehensive evaluation method

(a) TOPSIS method

The basic idea of the TOPSIS method was to construct a space using the positive ideal solution and the negative ideal solution based on the normalized original matrix [55]. The evaluated solution was considered as a point in this space. The distance between the point and the positive and negative ideal solutions is calculated to obtain the relative proximity measure $C_i$ value. The evaluation is then performed based on the $C_i$ value to assess the quality.

(1) Normalization of the original data matrix. In this study, all evaluation indicators are high-performance indicators. The normalization matrix $Y$ is established using the formula (13), $Y=(y_{ij})_{m\times n}$.

$$y_{ij}=a_{ij}/\sqrt{\sum_{i=1}^{m} a_{ij}^2} \quad (13)$$

(2) Constructing a weighted normalization matrix. Based on the weights calculated using the entropy weight method, the standard matrix $Y$ is weighted, resulting in the weighted normalized matrix $P$.

$$P=(p_{ij})_{m\times n}$$
$$p_{ij}=w_j y_{ij} \quad (14)$$

(3) Determining the positive ideal solution P+ and negative ideal solution P− based on the matrix. The positive ideal solution $P+=(p_1^+,\ p_2+,\ldots,\ pn+)$ and the negative ideal solution $P^-=(p_1^-,\ p_2^-,\ldots,\ p_n^-)$, where $pj^+=\max_{1\le i\le m13}\{P_{ij}\}$, $P_j^-=\min_{1\le i\le m13}\{P_{ij}\}$.

(4) Calculating the distances $D_i^+$ and $D_i^-$ between the evaluated objects and the positive and negative ideal solutions, respectively.

$$D_i^+=\sqrt{\sum_{j=1}^{n}(p_j^+-p_{ij})^2} \quad (15)$$

$$D_i^-=\sqrt{\sum_{j=1}^{n}\left(p_j^--p_{ij}\right)^2} \quad (16)$$

(5) Calculating the proximity measure $C_i$ between the evaluated objects and the optimal solution.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{17}$$

The $C_i$ values range from 0 to 1, where a higher value indicates a higher comprehensive level. The evaluated objects can be ranked based on their $C_i$ values.

(b) RSR method

This method was proposed by Chinese statistician in 1988 called Feng-tiao Tian [22]. The Rank Sum Ratio (RSR) refers to the average rank of rows (or columns) and possesses the characteristics of a continuous variable ranging from 0 to 1. A higher RSR value corresponds to a better evaluation result. The basic expression of RSR in a matrix with n rows (representing *n* evaluation objects) and m columns (representing m evaluation indicators) is as follows:

$$RSR_i = \frac{1}{m \times n}\sum_{j=1}^{m} R_{ij} \tag{18}$$

The calculation formula for Weighted Rank Sum Ratio (*WRSR*) is as follows:

$$WRSR_i = \frac{1}{n}\sum_{j=1}^{m} W_j R_{ij} \tag{19}$$

In formulas (18) and (19), where $i = 1, 2, \ldots, n$; $j = 1, 2, \ldots, m$; $R_{ij}$ represents the rank of the element in the $i_{th}$ row and $j_{th}$ column; $W_j$ represents the weight of the $j_{th}$ evaluation indicator.

The average rank of *WRSR* was denoted *as* "$\overline{R}$", the downward cumulative frequency "$p$" and Probit can be calculated as follows:

$$p = (n + 1 - \bar{R}) / n * 100 \tag{20}$$

Note that when the result of the calculation is 100, it is estimated by (1–1/4n).

$$\text{Probit } = u + 5 \tag{21}$$

Note that "$u$" represents the standard normal deviation corresponding to "$p$". When a Probit value greater than 6 indicates excellence, a *Probit* value between 4 and 6 indicates general, and a *Probit* value less than 4 indicates poor.

(c) Osculating value method

The Osculating value method could avoid the subjective factors in determining the weights of indicators in Grey Theory and overcome the construction difficulties of membership functions in fuzzy mathematical methods [56]. The basic principle is to identify the best and worst solutions by standardizing the evaluation indicators, and then calculate the Euclidean distance between each solution and the best or worst solution. And finally, the osculating value of each solution based on the Euclidean distance would be calculated. The solutions are then ranked according to their osculating values [57].

(1) Establishing an indicator matrix, and then the weighted standard matrix will be created after normalizing and weighting. This process is similar to the TOPSIS method, as shown in Formula (13) and Formula (14). Determining the "best solution" and the "worst solution", which is denoted as $P^+$ and $P^-$.
(2) Calculating the Euclidean distances $G_i^+$ and $G_i^-$ for each solution:

$$G_i^+ = \sqrt{\sum_{j=1}^{n} (p_{ij} - p_j^+)^2} \tag{20}$$

$$G_i^- = \sqrt{\sum_{j=1}^{n} (p_{ij} - p_j^-)^2} \tag{21}$$

(3) Calculating the closeness value $E_i$ for each solution and rank them

Let $G^+$ be the minimum value among the m $G_i^+$ values, and $G^-$ be the maximum value among the m $G_i^-$ values. The formula for calculating the osculating value $E_i$ for each solution is as follows:

$$E_i = \frac{G_i^+}{G^+} - \frac{G_i^-}{G^-} \tag{22}$$

When $G^+ = G_i^+$ and $G^- = G_i^-$, $E_i = 0$. At this point, the solution is closest to the optimal point. When $E_i > 0$, a larger $C_i$ value indicates that the solution is farther away from the optimal point, therefore, the solutions can be ranked based on the $E_i$ values to obtain "the most satisfactory solution".

(d) Combined ranking

The Combined ranking means the final ranking (result), the Serial Number Summation Theory [58] was applied to synthesize the evaluate results of the TOPSIS method, the RSR method, and the Osculating value method to determine the final results. When the summation of rankings of the three comprehensive evaluation methods is equal, the mode theory [59] is used to determine the ranking issue.

## Statistical analysis

To test the consistency of the evaluation results, *Kendall's* concordance coefficient was employed, with the independent variable being the rankings derived from three evaluation methods. Additionally, *Spearman's* correlation coefficient was utilized to examine the correlation, where the independent variables consisted of the rankings from the three evaluation methods, the combined rankings, and the international rankings as of December 2019. Both statistical analyses were conducted using SPSS software (SPSS Inc., Chicago, IL, USA) for Mac, with statistical significance defined at $P < 0.05$.

## Results

### Evaluation of competitive technical and tactical performance for multiple players

Table 2 presents the *TE* values, weights and evaluation results of 6 elite players in important competitions. It showed that the highest average *TE* among the four phases was $TE_3$ (0.540), the second was $TE_2$ (0.514), the third was $TE_1$ (0.508), and the lowest was $TE_4$ (0.425). The weights of *TE* were determined by using information entropy. The weights of $TE_1$, $TE_2$, $TE_3$, and $TE_4$ were 0.316, 0.172, 0.177, and 0.335, respectively.

It can be observed in Table 2 that the ranking of the three methods for the evaluation of the comprehensive technical and tactical of the 6 elite athletes was almost the same (except for the ranked 4 and 5 in the RSR method). Player A was ranked first, Player B was ranked second, Player C was ranked third, Player F was ranked fourth, Player E was ranked fifth, and Player D was ranked sixth. This indicated that the three comprehensive evaluation methods based on entropy weight were suitable for the evaluation of the comprehensive performance for elite table tennis players.

### Evaluation of a player's competitive technical and tactical performance across different time periods

Taking two rookie players, Player C and Player E, as examples, the following was the evaluation of their competitive technical and tactical performance across different time period.

#### *Evaluation of Player C*

Table 3 showed the *TE*, weights and evaluation results of Player C in 9 matches. It could be observed that the average value of Player C in $TE_2$ (0.543) was significantly higher than the average of 6 elite players (0.514), indicating his exceptional skills on the second and fourth shots. The average value of Player C in $TE_1$ (0.509) was relatively close to the average of 6 elite players (0.508), but his average value in $TE_3$ and $TE_4$ were all lower than the average of 6 elite players, indicating that his rallying phase was a weakness in his technique. Due to the variety of playing styles and technical specialties of table tennis players, the impact of technical indicators on their performance varies. The weights of $TE_1$, $TE_2$, $TE_3$ and $TE_4$ were 0.313, 0.223, 0.297, and 0.167, respectively. The results of the three comprehensive evaluation methods were not the same. Among them, the results of the TOPSIS method were completely consistent with the combined ranking, indicating that the TOPSIS method might be more

**Table 2** TE, weights and evaluation results of six players

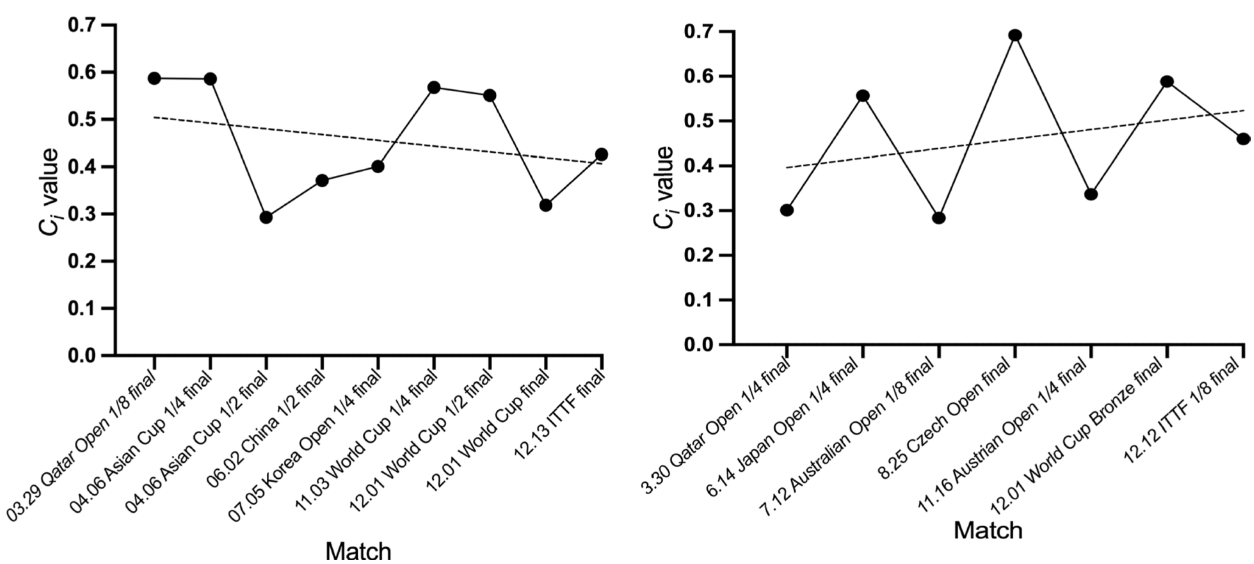
| | $TE_1$ | $TE_2$ | $TE_3$ | $TE_4$ | TOPSIS | | RSR | | | | | Osculating value | | Combined ranking | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $C_i$ | Rank | $WRSR_i$ | Rank / $\overline{R}$ | *P* (%) | *Probit* | Results | $E_i$ | Rank | Summation | Rank |
| *Player A* | 0.535 | 0.501 | 0.627 | 0.455 | 0.838 | 1 | 0.861 | 1 | 95.8 | 6.732 | Excellent | 0.000 | 1 | 3 | 1 |
| *Player B* | 0.536 | 0.532 | 0.599 | 0.440 | 0.813 | 2 | 0.857 | 2 | 83.3 | 5.967 | General | 0.166 | 2 | 6 | 2 |
| *Player C* | 0.517 | 0.546 | 0.503 | 0.419 | 0.471 | 3 | 0.639 | 3 | 50.0 | 5.431 | General | 2.783 | 3 | 9 | 3 |
| *Player D* | 0.488 | 0.496 | 0.502 | 0.390 | 0.161 | 6 | 0.278 | 6 | 16.7 | 4.033 | General | 4.730 | 6 | 18 | 6 |
| *Player E* | 0.496 | 0.535 | 0.494 | 0.408 | 0.334 | 5 | 0.443 | 4 | 66.7 | 5.000 | General | 3.740 | 5 | 14 | 5 |
| *Player F* | 0.475 | 0.461 | 0.513 | 0.438 | 0.382 | 4 | 0.423 | 5 | 33.3 | 4.569 | General | 3.616 | 4 | 13 | 4 |
| *Average* | 0.508 | 0.514 | 0.540 | 0.425 | *Kendall W = 0.975, p = 0.012** | | | | | | | | | | |
| *Information Entropy ($H_j$)* | 0.953 | 0.974 | 0.974 | 0.950 | | | | | | | | | | | |
| *Weights ($W_j$)* | 0.316 | 0.172 | 0.177 | 0.335 | | | | | | | | | | | |

*$^{***}$, $^{**}$, and $^{*}$ denotes statistical significance at the 0.1, 1, and 5% levels, respectively*

**Table 3** TE, weights, and evaluation results of Player C

| Matches | $TE_1$ | $TE_2$ | $TE_3$ | $TE_4$ | TOPSIS | | RSR | | Osculating value | | Combined ranking | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $C_i$ | Rank | $WRSR_i$ | Rank | $E_i$ | Rank | Summation | Rank |
| 2019.03.29 Qatar Open 1/8 final | 0.587 | 0.625 | 0.483 | 0.449 | 0.587 | 1 | 0.712 | 1 | 0.142 | 1 | 3 | 1 |
| 2019.04.06 Asian Cup 1/4 final | 0.615 | 0.614 | 0.454 | 0.471 | 0.586 | 2 | 0.693 | 2 | 0.161 | 2 | 6 | 2 |
| 2019.04.06 Asian Cup 1/2 final | 0.500 | 0.461 | 0.516 | 0.330 | 0.293 | 9 | 0.401 | 8 | 1.161 | 8 | 25 | 9 |
| 2019.06.02 China 1/2 final | 0.430 | 0.490 | 0.533 | 0.442 | 0.371 | 7 | 0.375 | 9 | 0.974 | 7 | 23 | 7 |
| 2019.07.05 Korea Open 1/2 final | 0.470 | 0.520 | 0.488 | 0.463 | 0.401 | 6 | 0.465 | 6 | 0.829 | 6 | 18 | 6 |
| 2019.11.03 World Cup 1/4 final | 0.432 | 0.509 | 0.637 | 0.562 | 0.568 | 3 | 0.608 | 5 | 0.255 | 3 | 11[a] | 3 |
| 2019.12.01 World Cup 1/2 final | 0.500 | 0.577 | 0.594 | 0.413 | 0.551 | 4 | 0.686 | 3 | 0.257 | 4 | 11[a] | 4 |
| 2019.12.01 World Cup final | 0.545 | 0.524 | 0.476 | 0.256 | 0.319 | 8 | 0.452 | 7 | 1.202 | 9 | 24 | 8 |
| 2019.12.13 ITTF final | 0.500 | 0.565 | 0.546 | 0.360 | 0.426 | 5 | 0.609 | 4 | 0.685 | 5 | 14 | 5 |
| *Average* | 0.509 | 0.543 | 0.525 | 0.416 | *Kendall W = 0.948, p = 0.004**** | | | | | | | |
| *Information Entropy ($H_j$)* | 0.839 | 0.885 | 0.847 | 0.914 | | | | | | | | |
| *Weights ($W_j$)* | 0.313 | 0.223 | 0.297 | 0.167 | | | | | | | | |

[a] denotes the summation of the three methods' ranking is equal; ****, **, and * denotes statistical significance at the 0.1, 1, and 5% levels, respectively*




(a) Player C (b) Player E

**Fig. 1** Performance fluctuations of Player C and Player E in 2019

suitable for evaluating comprehensive technical and tactical performance.

Figure 1 displayed the performance fluctuations of Player C based on the $C_i$ values of the TOPSIS method. He experienced fluctuating stages of peaks, valleys, rebounds, and declines throughout the year 2019. In the Qatar Open 1/8 final and the Asian Cup 1/4 final, Player C displayed his best performance, with $C_i$ values of 0.587

and 0.586, reaching the peak for the entire year. However, his technical status suddenly declined in the Asian Cup 1/2 final, with $C_i$ value was 0.293, marking the lowest point of 2019. This particular match had some psychological impact on the player, for he remained in a low state until the World Cup in November, and the China Open and Korea Open both failed during this period. During the World Cup, Player C's performance showed some improvement, performing well in the 1/4 final and 1/2 final with $C_i$ values of 0.568 and 0.551. However, his performance was average in the final, with $C_i$ value of 0.319. There was a slight recovery until the ITTF final. Overall, Player C's comprehensive performance in 2019 had its ups and downs, with a slight overall downward trend.

#### *Evaluation of Player E*

It can be observed in Table 4 that Player E's comprehensive performance in the returning and attacking phase, serving and returning rallying phase, was significantly higher than the average of 6 elite players. Only in the serving and attacking phase did his *TE* fall below the average, indicating that he already possessed remarkable performance. However, his weaknesses lie in the first and third shots. The weights of various technical indices were obtained, which were based on Player E's 7 matches. They were 0.334, 0.221, 0.227, and 0.218. The ranking results of four matches are completely consistent, while the other three matches were slightly different. When using the method of the summation of rankings, the results are consistent with the TOPSIS method.

Throughout the year, Player E's comprehensive performance exhibited a fluctuating pattern (Fig. 1), with periods of improvement, decline, further improvement, and subsequent decline. In August, during the final of the Czech Open, his performance reached its peak, with $C_i$ value of 0.692. The next notable performances were in December, during the World Cup where he secured third place, and in June, during the quarter-final of the Japan Open, with $C_i$ value of 0.588 and 0.557, respectively. The lowest technical status occurred in the quarterfinals of the Australian Open in July, with $C_i$ value of only 0.284. Overall, Player E's comprehensive performance in 2019 exhibited continuous fluctuations, with a slight upward trend.

### Comparison of the three comprehensive evaluation methods

The TOPSIS method, RSR method, and Osculating Value Method demonstrated a high degree of consistency in the evaluation process, with Kendall's concordance coefficient (*W*) exceeding 0.948 (as shown in Tables 2, 3, and 4). Additionally, the three methods exhibited a strong correlation, as indicated by Spearman's correlation coefficients, all of which were above 0.883 and statistically highly significant (Table 5) Moreover, the findings aligned closely with international rankings (as of December 2019), further

**Table 4** TE, weights, and evaluation results of Player E

| Matches | $TE_1$ | $TE_2$ | $TE_3$ | $TE_4$ | TOPSIS | | RSR | | Osculating value | | Combined ranking | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $C_i$ | Rank | $WRSR_i$ | Rank | $E_i$ | Rank | Summation | Rank |
| 2019.03.30 Qatar Open 1/4 final | 0.369 | 0.561 | 0.543 | 0.447 | 0.301 | 6 | 0.411 | 6 | 1.824 | 6 | 18 | 6 |
| 2019.06.14 Japan Open 1/4 final | 0.486 | 0.602 | 0.517 | 0.530 | 0.557 | 3 | 0.679 | 2 | 0.574 | 3 | 8 | 3 |
| 2019.07.12 Australian Open 1/8 final | 0.372 | 0.442 | 0.500 | 0.515 | 0.284 | 7 | 0.371 | 7 | 1.966 | 7 | 21 | 7 |
| 2019.08.25 Czech Open final | 0.632 | 0.500 | 0.558 | 0.424 | 0.692 | 1 | 0.672 | 3 | 0.000 | 1 | 5# | 1 |
| 2019.11.16 Austrian Open 1/4 final | 0.479 | 0.361 | 0.604 | 0.377 | 0.337 | 5 | 0.517 | 5 | 1.538 | 5 | 15 | 5 |
| 2019.12.01 World Cup Bronze final | 0.537 | 0.660 | 0.562 | 0.329 | 0.588 | 2 | 0.681 | 1 | 0.461 | 2 | 5# | 2 |
| 2019.12.12 ITTF 1/8 final | 0.415 | 0.718 | 0.566 | 0.438 | 0.460 | 4 | 0.670 | 4 | 1.124 | 4 | 12 | 4 |
| *Average* | 0.470 | 0.549 | 0.550 | 0.437 | *Kendall W = 0.952, p = 0.009**** | | | | | | | |
| *Information Entropy ($H_j$)* | 0.722 | 0.816 | 0.810 | 0.818 | | | | | | | | |
| *Weights ($W_j$)* | 0.334 | 0.221 | 0.227 | 0.218 | | | | | | | | |

# denotes the summation of the three methods' ranking is equal; ****, **, and * denotes statistical significance at the 0.1, 1, and 5% levels, respectively*

**Table 5** Correlation Coefficients of the three evaluation methods during three evaluation progress

| | | TOPSIS | RSR | Osculating value | Combined ranking | International ranking |
|---|---|---|---|---|---|---|
| Evaluation of multiple player's | TOPSIS | 1 | | | | |
| | RSR | 0.943** | 1 | | | |
| | Osculating value | 1.000** | 0.943** | 1 | | |
| | Combined ranking | 1.000** | 0.943** | 1.000** | 1 | |
| | International ranking | 1.000** | 0.943** | 1.000** | 1.000** | 1 |
| Evaluation of Player C | TOPSIS | 1 | | | | |
| | RSR | 0.900** | 1 | | | |
| | Osculating value | 0.983** | 0.883** | 1 | | |
| | Combined ranking | 1.000** | 0.900** | 0.983** | 1 | |
| Evaluation of Player E | TOPSIS | 1 | | | | |
| | RSR | 0.893** | 1 | | | |
| | Osculating value | 1.000** | 0.893** | 1 | | |
| | Combined ranking | 1.000** | 0.893** | 1.000** | 1 | |

**** , **, and * denotes statistical significance at the 0.1, 1, and 5% levels, respectively*

validating the practical relevance and applicability of these three methods.

The TOPSIS method performed the best in the evaluation process, as its evaluation results for elite table tennis players were all identical to the combined ranking results. The Osculating Value Method ranked second, with its evaluation results consistent with the combined ranking results twice. In contrast, the RSR method performed relatively less favorably. However, the RSR method not only allowed for ranking evaluation but also enabled the classification of players' performance into different categories. As shown in Table 2, by calculating the percentage p and the Probit values, the RSR results indicated that Player A was classified as "Excellent," while the other five players were categorized as "General." This suggests that Player A's performance is significantly superior to that of the other players.

## Discussion

### Relationship between comprehensive technical and tactical performance and TE

The comprehensive technical and tactical performance reflects a player's overall technical and tactical abilities, and it enables comprehensive comparisons among different players. Meanwhile, *TE* reflects each phased performance of the players. In sports training practice, the combination of them can provide an overall understanding of a player's performance level, while also allowing for analysis of each technical detail. It facilitates comprehensive comparisons among players and summarizes their technical characteristics.

Taking Player A and Player B as examples, their rankings in terms of the comprehensive technical and tactical performance are 1st and 2nd respectively, with $C_i$ values were 0.779 and 0.756. The difference between the two players is not significant from this view. However, by considering the four phases of *TE* (Table 2), it can be observed more specific information. Player A had the highest technical effectiveness in the serving and attacking phase (0.535), rallying phase I (0.627), and rallying phase II (0.455) among the 6 players. However, his effectiveness in the receiving and attacking phase(0.501) was weaker, ranking 5th. It is evidenced that Player A possessed comprehensive and outstanding comprehensive abilities, particularly excelling in the first and third shots and demonstrating strong rallying skills, but his receiving and fourth shot techniques required further improvement. Meanwhile, Player B's technical effectiveness for the four phases were 0.536, 0.532, 0.599, and 0.440, which ranking 1st, 3rd, 2nd and 2nd among 6 players. This indicated that Player B had a well-balanced skill in all aspects, with overall strong capabilities. His scoring skills were diverse, and once he identified the weaknesses of his opponents during a match, he could apply comprehensive technical and tactical measures to suppression them.

### Practical significance of evaluating of the competitive technical and tactical performance across time periods

(1) It allows for observing the impact of different types of competitions on players' performance. Different types of matches and different stages of a match can have an influence on a player's performance. Generally, the higher the importance of the competition, or the later the stage of the game, the stronger the athlete's will to win, and thus the higher the psy-

chological pressure, the more likely to affect their performance [60, 61]. By analyzing the evaluation of a player's performance in different matches, it is possible to observe this phenomenon. The comprehensive indicator values of Player C (Fig. 1) showed a significant decrease from the quarter-final to the semi-final of the Asian Cup. In the World Cup, the comprehensive indicator values continued to decline as the competition progressed from the quarter-final to the semi-final and then to the final. This indicated that different stages of the competition have had an impact on Player C's technical status. The reason is due to the technical and tactical are limited by the increasingly high level of the opponents, or the physical fitness decline as the game progresses, or there was a change in the athlete's psychology, a desire to win and a fear of losing. The specific reasons are worth reflecting on by coaches and athletes in the training. The two matches in which Player E (Fig. 1) showed the best competitive condition, that is with the highest value of the composite indicator, were the final of the Czech Open and the bronze medal match of the World Cup. This indicates that in the critical matches, Player E's performance were better displayed compared to regular matches, demonstrating the qualities of an excellent table tennis player.

(2) It is possible to analyze the characteristics of performance when competing against different opponents. When facing different opponents, athletes will show different technical status [6, 60]. The athletes' performance fluctuations can be clearly observed when they play against different opponents, so that targeted analysis and training to be conducted accordingly. In Fig. 1, the two matches with the lowest performance evaluations for Player C were the semi-final of the Asian Cup and the final of the World Cup, with the same opponent (Player A). It could be observed that Player C was unable to effectively utilize his techniques in these matches, resulting in generally low technical effectiveness values. While Player E's three matches with the lowest performance were the quarter-final of the Qatar Open, the eighth-final of the Australian Open, and the quarter-final of the Austrian Open. All the opponents were Chinese players, and all end in defeat. This indicates that his comprehensive performance was weaker when competing against Chinese players.

(3) Necessary psychological observation and regulation can be conducted. Good mental fitness is a guarantee for the technical and tactical performance of the game [6, 60]. When evaluating a player's performance, in addition to considering the nature of the match and the opponent's technical characteristics, it is also important to observe and regulate the player's psychological changes. The defeat in the semi-final of the 2019 Asian Cup had a significant impact on Player C, as he subsequently struggled in his performance in the following matches. His performance remained low for several consecutive months until his state started to recover in the World Cup in November (Fig. 1). Being in a relatively low performance for such a long period, it is necessary for the coach to not only enhance targeted training in terms of tactics and physical fitness but also provide necessary psychological regulation and support. Additionally, Player E demonstrated a dark horse quality in several important matches (the final of the Czech Open and the 3rd-4th place match in the World Cup). However, as seen in Fig. 1, his comprehensive fluctuated throughout the year, lacking stability, which could also be partly attributed to psychological factors.

### Limitations

This study exhibited three primary limitations. Firstly, it is important to acknowledge that our investigation is constrained to a relatively brief timeframe and is centered exclusively on a single sport. To enhance the generalizability and reliability of our present findings, future research endeavors should encompass more extensive observation periods and extend their scrutiny to encompass performance metrics in diverse sporting disciplines. Secondly, it is imperative for future research to consider the variances in competitive contexts. This entails examining factors such as the stages of a competition (e.g., start, middle, or end), the position of competitors (leading or trailing), and distinctions between male and female matches. By doing so, researchers can delve deeper into understanding how these contextual distinctions impact performance disparities. Thirdly, The comprehensive performance of athletes is a critically important concept, and its quantification and research hold significant implications for both competition and training. However, this study only employed fixed comprehensive evaluation methods for analysis. Future researchers could innovate more suitable mathematical or statistical approaches tailored to different sports applications.

## Conclusion

This article explores the application of different comprehensive evaluation methods to the evaluation of elite table tennis players' comprehensive technical and tactical performance, the results show that (1) The comprehensive evaluation method can help to solve the problem of evaluating the comprehensive performance of athletes, which can not only accurately evaluate the multiple athletes, but also longitudinally evaluate performance fluctuations of a single player in different time periods. (2) All three methods, the Entropy-based TOPSIS method, the RSR method, and the Osculating value method, showed to have strong applicability and high consistency, but due to their different principles, the evaluation results showed individual differences. The TOPSIS method performed more well. (3) In practical applications, comprehensive technical and tactical performance and phased-*TE* exhibit complementary effects in the analysis of table tennis performance. This approach facilitates a more in-depth and comprehensive representation of table tennis match analysis, providing practical applications for athletes and coaches, thereby contributing to the enhancement of training and competitive performance.

**Acknowledgements**
Not applicable.

**Authors' contributions**
Conceptualization, ZHC, MZL, QY; methodology, ZHC and MZL; formal analysis, ZHC and MZL; data processing, ZHC and MZL; writing—original draft preparation, ZHC, QY; writing—review and editing, QY; project administration, N/A; funding acquisition, N/A. All authors have reviewed and agreed to the published version of the manuscript. All authors read and approved the final manuscript.

**Funding**
This study was supported by Social Science Foundation of Jiangsu Province (NO. 23TYD006).

**Data availability**
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate**
Ethical review and approval were not required for this study in accordance with the requirements of Ethics Committee of the Institute of Physical Education, Soochow University. Written informed consent from the patients/participants or patients/participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare no competing interests.

**Author details**
[1]School of Physical Education, Soochow University, 50 Donghuan Road, Suzhou, Jiangsu Province 215021, China.

Received: 19 November 2024 Accepted: 21 February 2025
Published online: 10 March 2025

**References**

1. O'Donoghue P: An introduction to performance analysis of sport, vol. London and New York: Routledge Taylor & Francis Group; 2014. https://doi.org/10.4324/9781315816340.
2. Liu H, Cui Y, Zhang S, Gomez MA. Development and outlook of sports performance analysis. J Phys Educ. 2016;23(02):112–7. https://doi.org/10.16237/j.cnki.cn44-1404/g8.2016.02.016.
3. Passos P, Araújo D, Volossovitch A. Performance analysis in team sports, vol. London: Routledge, Taylor & Francis Group; 2017.
4. Yi Q, Li Y, Zhang M, Cui Y, Liu T, Zhang S, Gong B, Huang Z, Zhou C, Ruano MáG, et al. Performance analysis: past, present and future. J Shanghai Univ Sport. 2023;47(02):88–103.
5. Zhang H. Computer diagnosis and analysis of ball games, vol. Heilongjiang: Heilongjiang Science and Technology Press, Harbin; 2006.
6. Tian M. Sports training, vol. Beijing: People's Sports Press; 2000.
7. Hughes MD, Bartlett RM. The use of performance indicators in performance analysis. J Sports Sci. 2002;20(10):739–54. https://doi.org/10.1080/026404102320675602.
8. Zhang S, Lorenzo A, Gómez M-A, Liu H, Gonçalves B, Sampaio J. Players' technical and physical performance profiles and game-to-game variation in NBA. Int J Perform Anal Sport. 2017;17(4):466–83. https://doi.org/10.1080/24748668.2017.1352432.
9. Zhang X, Xiao D, Zhou X, Fang W. The construction and application of dynamic three-phase method on table tennis technique and tactics. China Sport Sci Technol. 2018;54(01):80–3. https://doi.org/10.16470/j.csst.201801011.
10. Wu H. Assessment of technical abilities and technical analysis of Chinese table tennis players participating in the 1988 Olympic Games. Chin J Sports Sci Technol. 1988;03:34–49. https://doi.org/10.16470/j.csst.1988.03.004.
11. Straub G, Klein-Soetebier T. Analytic and descriptive approaches to systematic match analysis in table tennis: a review. German J Exerc Sport Res. 2017;47(2):95–102. https://doi.org/10.1007/s12662-016-0431-2.
12. Yang Q, Zhang H. Construction and application of"four phase evaluation theory"technique and tactics for table tennis. J Tianjin Univ Sport. 2014;29(05):439–42. https://doi.org/10.13297/j.cnki.issn1005-0000.2014.05.013.
13. Wu F, Liu G, Hua C, Wu J. Research on modifying the methods of studying table tennis technique and tactics. China Sport Sci Technol. 2014;50(01):71–4. https://doi.org/10.16470/j.csst.2014.01.010.
14. Zhang J, Feng J, Hou S, Shi Z, Ren J. Development and application of effect evaluation model for table tennis technique and tactics. J Tianjin Univ Sport. 2020;35(06):740–4. https://doi.org/10.13297/j.cnki.issn1005-0000.2020.06.020.
15. Xiao D, Zhou X, Liu H, Qin Z, Yu Y. The construction and application of double three-phase method on table tennis technique and tactics. China Sport Sci Technol. 2018;54(05):112–6. https://doi.org/10.16470/j.csst.201805017.
16. Jiang J, Yao J. Evaluation on tactical skills in table tennis single match and reconstruction and applications of its diagnostic methods. J Tianjin Univ Sport. 2015;30(05):432–7. https://doi.org/10.13297/j.cnki.issn1005-0000.2015.05.011.
17 Zhang H, Liu W, Hu J, Liu R. Evaluation of elite table tennis players' technique effectiveness. J Sports Sci. 2017;31:1526–34. https://doi.org/10.1080/02640414.2013.792948.
18. Tamaki S, Yoshida K, Yamada K. A shot number based approach to performance analysis in table tennis. J Hum Kinet. 2017;55(1):7–18. https://doi.org/10.1515/hukin-2017-0002.
19. Yang Q, Li M, Zhou Z, Zhang H. Exploring the structure of the shot effectiveness model for elite table tennis players. BMC Sports Sci Med Rehabil. 2023;15(1):127. https://doi.org/10.1186/s13102-023-00736-x.
20. Wang Y, Sun Z. Research progress of medical comprehensive evaluation methods. J Central South Univ (Medical Science). 2005;02:228–32.
21. Hwang CL, Yoon K. Methods for multiple attribute decision making. In Multiple attribute decision making: methods and applications a state-of-the-art survey. edn. Berlin, Heidelberg: Springer Berlin Heidelberg; 1981. Pp.58–191.
22. Tian F. Application of rank-sum ratio method in hospital statistics. Chin J Hosp Stat. 1994;1(1):41–6.
23 Qader M, Zaidan B, Zaidan A, Ali S, Kamaluddin M, Radzi W. A methodology for football players selection problem based on multi-measurements

criteria analysis. Measurement. 2017;111:38–50. https://doi.org/10.1016/j.measurement.2017.07.024.
24. Pehlivan NY, Ünal Y, Kahraman C. Player selection for a national football team using Fuzzy AHP and Fuzzy TOPSIS. J Mult-Valued Logic Soft Comput. 2019;32(5–6):369–405.
25. Zhao J. TOPSIS analysis of offensive and defensive indicators of the top four teams in the 2014–2015 season of the Chinese Women's Basketball League. Chin J Sports Sci Technol. 2015;51(05):40–4. https://doi.org/10.16470/j.csst.201505007.
26. Dadelo S, Turskis Z, Zavadskas EK, Dadeliene R. Multi-criteria assessment and ranking system of sport team formation based on objective-measured values of criteria set. Expert Syst Appl. 2014;41(14):6106–13. https://doi.org/10.1016/j.eswa.2014.03.036.
27. Chang C-W. Construction of value classification model by tracking NBA center players' performance with virtual IoT tagging technology. J Internet Technol. 2020;21(1):295–303. https://doi.org/10.3966/160792642020012101025.
28. Kong L, Zhang H, She J, Liu R. Study on technical training monitoring of outstanding female table tennis athletes. J Shanghai Univ Sport. 2016;40(01):51–7. https://doi.org/10.16099/j.sus.2016.01.008.
29. Zhao X, Tang J. Application of TOPSIS method in the evaluation of table tennis match quality: a case study of Ma Long/Fan Zhendong match. J Cap Univ Phys Educ Sports. 2017;29(03):249–53. https://doi.org/10.14036/j.cnki.cn11-4513.2017.03.013.
30. Saqlain M, Jafar N, Hamid R, Shahzad A. Prediction of cricket world Cup 2019 by TOPSIS technique of MCDM-A mathematical analysis. Int J Sci Eng Res. 2019;10(2):789–92.
31. Sakınç İ, Açıkalın S, Soygüden A. Evaluation of the relationship between financial performance and sport success in European football. 2017. https://doi.org/10.7752/jpes.2017.s1003.
32. Guo D, Hu Q. Comprehensive evaluation of outstanding basketball players' game performance. Sports Sci. 2000;06:25–8.
33. Hu M, Sun Q, Rong H. Comparative study on offensive and defensive capabilities of teams in the 16th World Men's Basketball Championship. Chin J Sports Sci Technol. 2011;47(01):34–9. https://doi.org/10.16470/j.csst.2011.01.007.
34. Hou X, Guang H, Li X. Comparative study on the offensive and defensive strength between the Chinese men's basketball team and their opponents in the 27th Asian Men's Basketball Championship. J Shanghai Univ Sport. 2014;38(02):87–94. https://doi.org/10.16099/j.cnki.jsus.2014.02.018.
35. Wei L, Fang C, Yu Y. RSR evaluation of attacking ability of the setter and receiver in women's volleyball. Sports Sci Res. 2003;04:61–3. https://doi.org/10.19715/j.tiyukexueyanjiu.2003.04.017.
36. Guo R, Ge C, Hao L, Yu Z. Evaluation of the offensive and defensive ability levels in high-level women's volleyball matches at the Olympic Games. J Beijing Sport Univ. 2018;41(01):109–16. https://doi.org/10.19582/j.cnki.11-3785/g8.2018.01.016.
37. Yang X, Feng H. The, "high and fast" characteristics of spike and block in volleyball and their application in the selection of excellent auxiliary attackers. J Xi'an Inst Phys Educ. 2019;36(06):757–62. https://doi.org/10.16063/j.cnki.issn1001-747x.2019.06.021.
38. Cao W. Analysis of the contemporary world football strength pattern and tactical approach from the perspective of the World Cup. Chin J Sports Sci Technol. 2011;47(01):65–8+102. https://doi.org/10.16470/j.csst.2011.01.012.
39. Ren B. Research on the offensive and defensive abilities of the Chinese men's basketball team in the 27th Asian Men's Basketball Championship using the closeness value method and priority method. Master. Wuhan Sports University; 2014.
40. Wang P, Li D. Analysis of the closeness value of the offensive and defensive abilities between the Chinese team and opponents in the 28th Asian Men's Basketball Championship. J Beijing Sports Univ. 2016;39(12):131–8. https://doi.org/10.19582/j.cnki.11-3785/g8.2016.12.021.
41. Liu B, Wu X. Evaluation of hospital medical work quality in China based on the closeness value method. Chin J Hosp Stat. 2007;03:209–10.
42. Li D, Yang Y. Analysis of enterprise product innovation performance based on process and evaluation using the closeness value method in technology management research. Sci Technol Manag Res. 2009;29(01):149–52.
43. Xue W, Liu Z, Sun Y, Hao J. Application of the closeness value method in the evaluation of ground water environmental quality. Environ Eng. 2003;01:67–9+66. https://doi.org/10.13205/j.hjgc.2003.01.024.
44. Liu M, Zhao Y, Song Z, Xia X, Zhang Y, Li S, Wang H, Xu L. Comprehensive evaluation of demonstration effect of new millet varieties based on the closeness value model: a case study of Yugu 18. Chin Agric Sci Technol Bull. 2017;19(11):42–8. https://doi.org/10.13304/j.nykjdb.2017.0059.
45. Bao X, Pan N, Yang S, Liu Y, Li W, Li X. Comprehensive evaluation of the quality of child health work in China based on TOPSIS, RSR, and linear interpolation method. Chin J Child Health Care. 2017;25(09):967–70. https://doi.org/10.11852/zgetbjzz2017-25-09-32.
46. Li Y, Li Y, Guo L, Ma L, Tian Q. Comprehensive evaluation of the quality of child health work in Henan Province using TOPSIS, rank-sum ratio, and linear interpolation method. Modern Prev Med. 2019;46(20):3704–8+3727.
47. Zhang H, Zhou Z, Yang Q. Match analyses of table tennis in China: a systematic review. J Sports Sci. 2018;36(23):2663–74. https://doi.org/10.1080/02640414.2018.1460050.
48. Cheng Y. Comparative analysis of the three-phase and four-phase evaluation theories for elite male table tennis players with left-handed backhand strokes. Chin Sports Coach. 2017;25(04):50–2. https://doi.org/10.16784/j.cnki.csc.2017.04.018.
49. Lü S. Analysis of the technical and tactical characteristics of outstanding table tennis players Ma Long and Boll. Master. Liaoning Normal University; 2019.
50. Zhao W. Comparative analysis of the technical and tactical characteristics of top male table tennis players Ma Long and Ovtcharov. Master. Tianjin University of Sports; 2019.
51. Zhong Q, Li P, Chen J. Analysis of competitive performance characteristics of female tennis players based on "four-stage evaluation method." Fujian Sports Sci Technol. 2019;38(06):40–3.
52. Liu C, Wang B. Construction and application of "four-phase evaluation theory" for men's badminton singles matches. J Hebei Sport Univ. 2020;34(01):73–8.
53. Qiu W. Management Decision Making and Applied Entropy Theory, vol. Beijing: China Machine Press; 2002.
54. Pu H. Construction research on the evaluation system of sustainable development of campus football based on entropy method: taking Sichuan campus football as an example. J Chengdu Sport Univ. 2017;43(03):115–20+126. https://doi.org/10.15942/j.jcsu.2017.03.018.
55. Sun Z. Medical comprehensive evaluation methods and their applications, vol. Beijing: Chemical Industry Press; 2006.
56. Heng D, Hong W, Lin G, Zhu Z, Mo M. The closeness value method for multi-objective decision-making and its application research. Agric Syst Sci Compr Res. 2001;17(02):96–8.
57. Yang G, Wang Z, Sun B, Chen T. Application of closeness value method in wellbore type optimization of coalbed methane wells. Petroleum Drilling Tech. 2013;41(02):49–53. https://doi.org/10.3969/j.issn.1001-0890.2013.02.010.
58. Hu Z, Lü X, Qi M. Serial sum theory and its application in comprehensive economic benefit ranking. Quantity Econ Tech Res. 1996;01:59–62. https://doi.org/10.13653/j.cnki.jqte.1996.01.011.
59. Bai X, Zhao S. Study on the advantages and disadvantages of various comprehensive evaluation methods. Stat Res. 2000;17(07):45–8. https://doi.org/10.19343/j.cnki.11-1302/c.2000.07.008.
60. Ren J, Zhang H, Shi Z, Zhang J. Analysis of palyer's mental status during table tennis competition based on variation of score. China Sport Sci. 2013;33(11):94–7. https://doi.org/10.16469/j.css.2013.11.013.
61. Shi Z, Zhang J, Ren J, Huang R, Hou S. Relationship between match importance, competition process and mental state of elite table tennis athletes. China Sport Sci. 2015;35(06):41–4+72. https://doi.org/10.16469/j.css.201506006.

## Publisher's Note