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Research on the impact of competition system reform on badminton development based on curve fitting

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ABSTRACT

Currently the powerful nation of badminton in the world are monopolized by some countries of Middle-South Asia, drawing on the experience of successful reform of table tennis, the 21 points new scoring system of badminton comes shining through. In this paper, it uses the classical probability model to establish a functional relationship between the winning probability of single round and the winning probability of single game, through observation, and uses hyperbolic tangent curve fitting method to simplify the expression, and thus leads to the indicators of the game time. By calculating the distance of each evaluated object separately to the ideal and non-ideal solution, coupled with the comparison, the comprehensive evaluation of four different competition systems are obtained. However, there is no absolute advantage or disadvantage for each competition system. Therefore, in the evaluation process, this paper uses the relative analysis and comprehensive evaluation methods to analyze the four options given in the title. The outcome is that the best of three innings for 21 points system and the best of five innings for 15 points system are more reasonable competition system.

KEYWORDS

Curve fitting;
Classical probability;
Gray correlation;
TOPSIS algorithm;
Badminton;
21-point system.

INTRODUCTION

Since December 11, 2005, the International Badminton Federation Council decided that the 21 points system will be put into full trial since February 1, 2006, this decision is suitable for men and women's singles, doubles and mixed doubles and other five projects. In April 2006, the "Thomas-Uber" held in Japan used the new game system of the 21-points. After a vote in the IBF meeting on May 6 Tokyo, Japan, all members of the IBF voted and decided to abolish the 15 points system and officially opened the 21 points system. New scoring system was first used in the 2008 Beijing Olympic Games; the new game system makes the game shorter and more confrontational[1-3].

In this paper, it establishes four sub-models, namely the player's athletic ability model, probability model of single round, probability model of single inning and probability model of single game, thereby obtains the probability function relationship between that of single round and that of single inning and between that of single round and that of single game, and simplifies the function expression by fitting method[4-6]. Because there is no absolute advantage or disadvantage for each game system, in the evaluation process, it uses a method of relative analysis and comprehensive evaluation analysis to study, obtains the conclusion that which scoring system should be adopted under normal game system and special competition system[7-9]. In order to study more conveniently, we assume: the result of the game is only related with the player's technical level, which does not consider any kind of opponent's interference; neither take into account other factors (including referees, stadium and spectators, etc.). In each round of the game, the winning probability of athlete is certain, namely it has no relationship with the points in each game. Any game must be completed within the stipulated time, namely there are no ballot or other non-scoring factors that determine the outcome of the match. For all game system, the factors that impact the same athletes' play level in a single round is consistent and consider only in the singles match[10].

Since IBF adopted the new rules "direct scoring system of 21 points", the impact of the new game system on badminton competition law has received widespread concern. More media and professional article analyzes the possible impact of new competition system on the game, mostly based on visual observation and subjective description, but they lack analysis of the change reasons.

CLASSICAL PROBABILITY MODEL ANALYSIS OF SINGLE ROUND AND SINGLE FIELD PROBLEMS

Athletes' competition level model

There are many factors that impact the technological level play of a badminton athlete, including the speed, strength, skill, responsiveness and psychological quality. At the same time, different athletes have different characteristics on links of return of serve; serve, the first three shots and the ability of Cosco kill. It is of a great difficulty to weigh all relevant factors and make a comprehensive evaluation on the spot competitive level of athletes. Therefore, this paper presents a simplified model, and under the premise that it does not affect the validity of the model, it can be considered that the technical level of athletes can be measured by using a standardized indicator μ. Here, μ is defined as the athletes' inherent competition technical level, only when $\mu_1 > \mu_2$, it can be considered that the technical level of athlete a is better than the technical level of athlete b.

Meanwhile, in athletic competitions we also consider any kind of non-technical factors. After analyzing many aspects, whether athletes can play well in the game is related with many factors, and these factors all belong to random variables, the accurate modeling process is relatively difficult, and in the modeling it should be considered mutually.

According to the central limit theorem of independent distribution, we suppose that the spot competitive ability of athlete in a single round is a random variable X. And we have the formula (1):

$$X \sim N(\mu,\sigma^2) \quad (1)$$

Wherein μ represents the inherent technical level of athletes (the skill level in the average state), σ represents the stability of the athletes' state play (the degree deviation of spot levels from the inherent level).

The probability model of a single round

Suppose that in a round of athlete a and athlete b, the spot play level of athlete a is X_1, the spot level of play for athlete b is X_2, the winning probability of athlete a in this round is: $P\{X_1 > X_2\}$.Since the basic assumption does not consider the mutual interference between athletes, that is the random variables X_1 and X_2 are independent and identically distributed.

Because $X_1 \sim N(\mu_1,\sigma_1^2)$, $X_2 \sim N(\mu_2,\sigma_2^2)$, the probability density function of X1 is:

$$f_1(x)=\frac{1}{\sqrt{2\pi}}\exp(-\frac{(x-\mu_1)^2}{2\sigma_1^2}) \quad (2)$$

The probability density function of X2 is:

$$f_2(x)=\frac{1}{\sqrt{2\pi}}\exp(-\frac{(x-\mu_2)^2}{2\sigma_2^2}) \quad (3)$$

The joint probability density function of X1 and X2 is:

$$f(x,y)=\frac{1}{2\pi\sigma_1\sigma_2}\exp(-\frac{(x-\mu_1)^2}{2\sigma_1^2}-\frac{(x-\mu_2)^2}{2\sigma_2^2}) \quad (4)$$

The probability of a winning the game in a single round is as follows:

$$p=\iint_{x>y}\frac{1}{2\pi\sigma_1\sigma_2}\exp(-\frac{(x-\mu_1)^2}{2\sigma_1^2}-\frac{(x-\mu_2)^2}{2\sigma_2^2})dxdy \quad (5)$$

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The probability of b winning the game in a single round is $q = 1 - p$.

The winning probability model in a single round

By the original assumption (2), the winning probability of a single inning of athlete a and b can be calculated by using classical probability theory. Through the background condition of the problem analysis, respectively calculate the probability of appearing the follow ball and not appearing the follow ball. Analyze the case that athlete a wins. (Because here a, b has symmetry, so only analyzing the situation that a wins does not affect the substance of the issues)

Case 1: When the situation does not arise that the two side battle into (i-1) even, athlete a has won i balls, then this round ends. The analysis shows that:

$$\mathbf{P(A_i) = \sum_{n=i}^{\infty} A_n} \quad (6)$$

Analysis shows that each round can be seen as a Bernoulli trial, then:

$$\mathbf{P(An) = C_{n-1}^{i-1} p^{i-1} q^{n-i} p = C_{n-1}^{i-1} p^{1} q^{n-i}}$$
$$\mathbf{(n = i + k, k = 0,1,2,\cdots,i-2)} \quad (7)$$

Case 2: when the situation arises that the two side battle into (i-1) even, the parties continue the game until a is 2 points more than b, and a is less than the upper limit of competition rounds, then a wins this round.

The above analysis shows that, at the moment the game has fights for n rounds, $n = 2(i-1) + 2m$ where in $m = 1,2,3\cdots$.

For this problem it can be divided into three stages to analyze, the first stage is the first $2(i-1)$ rounds, the two parties a, b each win $i-1$ rounds; the second stage fights $2m$ balls, where each of the two rounds can be seen as a round; in each round of the $m-1$ former rounds, each a, b wins a round; in the m rounds wins two-rounds and wins this inning, namely:

$$\mathbf{P'(An) = C_{2(i-1)}^{i-1} p^{i-1} q^{i-1} (2pq)^{m-1}}$$
$$\mathbf{p^2 = C_{2(i-1)}^{i-1} p^{i+1} q^{i-1} (2pq)^{m-1}} \quad (8)$$

Therefore when the credit system is i, the winning probability of a to win every inning is:

$$\mathbf{f_i(p) = \sum_{k=0}^{i-2} C_{i+K-1}^{i-1} P^i q^k + \sum_{m=1}^{\infty} C_{2(i-1)}^{i-1} P^{i+1} q^{i-1} (2pq)^{m-1}}$$
$$\mathbf{= p^i \sum_{k=0}^{i-2} C_{i+K-1}^{i-1} q^k + C_{2(i-1)}^{i-1} P^{i+1} q^{i-1} \frac{1}{1-2pq}} \quad (9)$$

Make the relational diagram between the winning probability p of a single round and the winning probability $f_i(p)$ of a single inning by using MATLAB software (Figure I); Here expanse the definition of i, define $i = 7,11,17,21,27$ (in the assumption only define $i = 11,21$, here expand the value of i, in the later text i still remains the definition of the original assumption). Figure 1 shows the relational diagram between the winning probability p of a single round and the winning probability $f_i(p)$ of a single inning when $i = 7$.

The function line in Figure 1 respectively represents the functional relationship between the winning probability of a single round and the winning probability of a single inning under a seven-point system. According to the same method, when $i = 15,17,21,27$, the winning probability of a single round can show the comprehensive athletic ability of the athlete; in accordance with the contingency of the game defined in the question, it can be considered that the winning probability of a single inning is completely unrelated with the winning probability of a single round; the competition results are absolutely accidental, the winning probability is 0.5; when the winning probability of a single inning is completely determined by the winning probability of a single round, there is a big economic gap between the players, the game has absolutely no chance (Figure 1); the higher the point system that the game rule adopts, the closer the function curve is to the function line of no chance; when the game rules adopt a lower points system, the curve is more closer to the function line of entire chance. The inclination in graph 1 reflects the contingency under different points system, from 7 points to 27 points system, the α of each curve successively increases, the chance reduces in turn, α shows a negative correlation with the contingency; the $x = 0.5$ and $y = 0.5$ as defined in Figure 1 are the two asymptotes; when α changes from 0 to ∞, the curve sweeps over $[0,0.5]*[0,0.5]$ and $[0.5,1]*[0.5,1]$ two regions; in the next model, we use to represent the accidental indicators under different

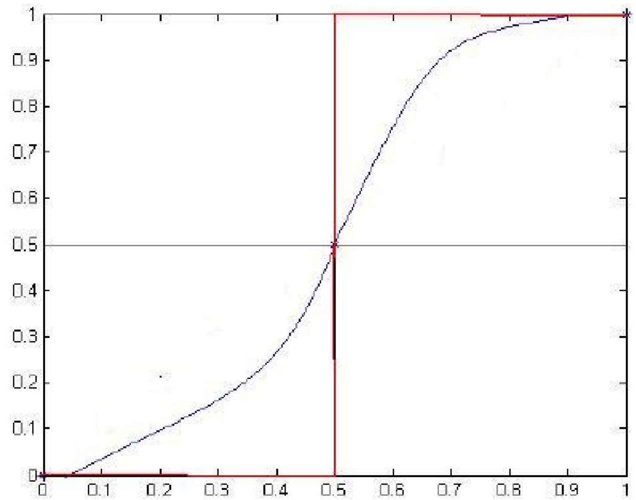

Figure 1 : The functional relationship between the winning probability of a single round and the winning probability of a single inning under a seven-point system

competition system, which brings huge convenience to calculation.

The probability model of a single inning

Badminton competition generally uses the rules of h wins in $2h-1$ innings; assuming in the $2h-1$ games of athletes a and b, each game is independent of each other, that the athlete a has the same winning probability, that is $f_i(p)$. Set event $B(s)$ is "b wins s innings totally, and a wins the final victory", then:

$$P(B((s)) = C_{h+s-1}^{s}(1-f_i(p))^s f_i^{\,h}(p) \quad (10)$$

Assuming the event B is "a wins the game", then:

$$P(B) = \sum_{s=0}^{h-1} P(B((s)) = f_i^{\,h}(p)\sum_{s=0}^{h-1} C_{h+s-1}^{s}(1-f_i(p))^s \quad (11)$$

So we have the following expression:

$$\varphi_i(2h-1,h,p) = f_i^{\,h}(p)\sum_{s=0}^{h-1} C_{h+s-1}^{s}(1-f_i(p))^s \quad (12)$$

According to the calculation method given above, the winning probability of a single game is the function of the winning probability of a single inning; therefore, it is also the function of the winning probability of a single round; through MATLAB it gives the functional relationship between the winning probability of a single round and the winning probability of a single game under four different competition systems; by observing the function graph, we find that the images all go through fixed point $(0.5,0.5)$, the graphics is very similar to the hyperbolic tangent function diagram, so here we use the hyperbolic tangent function to carry through curve fitting.

By equation (9) and (12), we can obtain the functional relationship between the winning probability of a single round and the winning probability of a single game through the composite functional relationship. The expression will be relatively more complex, so by curve fitting we approximately fit the complex polynomial into relatively simple hyperbolic tangent function; essentially it carries out the one step inverse operation of power series expansion.

Here we use the fitting function $g(x)$, namely:

$$g(x) = \frac{2}{1+\exp(-2\alpha(x-0.5))} - 0.5 \quad (13)$$

By fitting function $\varphi_i = (2h-1, h, p)$ can be approximately calculated as follows:

$$\varphi_i(2h-1,h,p) \approx g(p,\alpha_h^{(i)}) = \frac{2}{1+\exp(-2\alpha_h^{(i)}(p-0.5))} - 0.5 \quad (14)$$

Wherein, $\alpha_h^{(i)}$ is the inclination of the corresponding fitting function when the competition system is (i,h).

TABLE 1: Inclination under the four different game systems

competition system	Inclination $\alpha_h^{(i)}$
Best of five innings for 15 points	4.1471
Best of three innings for 21 points	4.2948
Four wins in seven innings for 15 points	4.2960
Best of five innings for 21 point	4.4620

TABLE 2 : Comprehensive evaluation table of four programs

\	Contingency indicators	Intense degree
Best of five innings for 15 points system	0.4492	0.3548
Best of three innings for 21 points system	0.4145	0.2991
Four wins in seven innings for 15 points system	0.4138	0.3975
Best of five innings for 21 points system	0.3787	0.3447

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Obtained by the MATLAB curve fitting program we obtain the inclination $\alpha_h^{(i)}$ under four different competition systems, the specific values are shown in TABLE 1.

The range of value p used in the fitting process is $(0.3,0.7)$ to improve the accuracy of curve fitting, and this method of removed fitting improves the consistency of the fitting curve to some extent; According to the actual situation, the range of curve fitting variable p is $(0.3,0.7)$; and when $p \in (0,0.3)$ the function value is a constant 0, when $p \in (0.7,1)$ the function value is a constant 1.

Through the above analysis, we can make the following approximation on $\varphi_i(2h-1,h,p)$.

$$\varphi_i(2h-1,h,p)=\begin{cases} 0 & ,\ (0<p<0.3) \\ \dfrac{2}{1+\exp(-2\alpha_h^{(i)}(p-0.5))}-0.5 & ,\ (0.3<p<0.7) \\ 1 & ,\ (0.7<p<1) \end{cases} \quad (15)$$

THE EVALUATION MODEL ANALYSIS BASED ON TOPSIS GRAY CORRELATION DEGREE

Here we do not repeat the concrete steps of the method, but give directly the evaluation form in TABLE 2, obtain the comprehensive evaluation value of each option.

Right here we do not consider the weight changes, suppose the weight of the intensity degree index is 0.6, the weight of the contingency index is 0.4; in the previous model, we have already mentioned that the intensity index is a function on p; but here we use $p = 0.4$ to approximately represent the average intensity under certain competition system (temporarily ignoring the differences of players), we can draw the following evaluation form (see TABLE 2).

Substitute the weights into the table and obtain the weighted decision-making specification matrix Z :

$$Z=\begin{pmatrix} 0.1797 & 0.2129 \\ 0.1658 & 0.1795 \\ 0.1655 & 0.2385 \\ 0.1515 & 0.2068 \end{pmatrix}$$

Select the target sequences $c = (0.1515, 0.2385)$ and seek the gray values of four kinds of solutions with the

TABLE 3 : The final score statistics of men's badminton singles in London Olympic Games 2012.08.05

First game		Second game		Third game	
1:	0	0:	1	1:	0
1:	1	1:	1	1:	1
1:	2	1:	2	2:	1
2:	2	1:	3	2:	2
3:	2	2:	3	2:	3
3:	3	3:	3	3:	3
4:	3	4:	3	3:	4
5:	3	4:	4	4:	4
5:	4	4:	5	5:	4
5:	5	5:	5	5:	5
5:	6	5:	6	6:	5
6:	6	6:	6	7:	5
7:	6	6:	7	8:	5
7:	7	6:	8	8:	6
8:	7	7:	8	8:	7
8:	8	7:	9	8:	8
9:	8	7:	10	8:	9
10:	8	7:	11	9:	9
11:	9	7:	12	9:	10
12:	9	7:	13	9:	11
12:	10	8:	13	10:	11
13:	10	8:	14	10:	12
13:	11	8:	15	11:	12
14:	11	8:	16	12:	12
15:	11	8:	17	12:	13
16:	11	9:	17	13:	13
16:	12	9:	18	14:	13
17:	12	9:	18	15:	13
17:	13	10:	19	15:	14
18:	13	10:	20	15:	15
19:	13	10:	21	16:	15
19:	14			16:	16
19:	15			17:	16
20:	15			18:	16
21:	15			18:	17
21:	15			18:	18
				19:	18
				19:	19
				19:	20
				19:	21

parent sequence, which is $r_1 = 0.0174, r_2 = 0.0198, r_3 = 0.0217, r_4 = 0.0217, r_4 = 0.0208$.

Through the above analysis, four wins in seven innings for 15 points and best of five games for 21 point are more reasonable competition systems from the number of games and the scores in each inning.

ANALYSIS OF TIME INDICATOR EVALUATION MODEL

This model only considers the impact of canceling rally point system on the total match time, and assumes other conditions are the same. Conduct statistic on the data in each round of the whole game for A, B and obtain the probability of winning a continuous i scores.

Conduct statistical summary on the data in the whole match for player A, obtain the proportion of A winning consecutive i goals in total scores:

$$P_i(A) \quad (i = 1,2,3,4\ldots) \tag{16}$$

According to the formula (17) and formula (18), sum formula (16) and obtain the total score probability of pre- reform $N_A{}'$ and post-reform N_A:

$$N_A = \sum_{i=1}^{n} i \cdot P_i(A) \tag{17}$$

$$N_A{}' = \sum_{i=1}^{n} (i-1) \cdot P_i(A) \tag{18}$$

The proportional relationship between the total score probability and the match time before and after the reform is:

$$\frac{h_A{}'}{h_A} = \frac{N_A}{N_A{}'} \tag{19}$$

Come to the total match time before the reform under the same scenario:

$$h_A{}' = \frac{N_A}{N_A{}'} \cdot h_A \tag{20}$$

Conduct statistical summary on the data in the whole match for player B, obtain the proportion of B winning consecutive i round goals in total scores:

$$P_i(B) \quad (i = 1,2,3,4\ldots) \tag{21}$$

According to the formula (22) and formula (23), sum formula (21) and obtain the total score probability of pre- reform $N_B{}'$ and post-reform N_B:

$$N_B = \sum_{i=1}^{n} i \cdot P_i(B) \tag{22}$$

$$N_B{}' = \sum_{i=1}^{n} (i-1) \cdot P_i(B) \tag{23}$$

The proportional relationship between the total score probability and the match time before and after the reform is:

$$\frac{h_B{}'}{h_B} = \frac{N_B}{N_B{}'} \tag{24}$$

Come to the total match time before the reform under the same scenario:

$$h_B{}' = \frac{N_B}{N_B{}'} \cdot h_B \tag{25}$$

Conduct data statistics for each of the rivals, there is a certain correlation between the data, so seek the average game of the two and finally get the total match before the reform:

$$h = \frac{h_A{}' + h_B{}'}{2} \tag{26}$$

In order to better verify the change of the total match time before and after canceling the rally point system, take the data of Lee Chong Wei and Lin Dan in the

TABLE 4 : The statistics data of Lin Dan and Lee Chong Wei in three games

Side-out scoring system			Rally points system		
Score	**Lee Chong Wei**	**Lin Dan**	**Score**	**Lee Chong Wei**	**Lin Dan**
1	0.34	0.4	0	0.34	0.4
2	0.28	0.32	1	0.28	0.32
3	0.3	0.18	2	0.3	0.18
4	0.08	0.24	3	0.08	0.24
	2.12	2.54		1.12	1.4

the total time after the reform: 1.5 (hour); the total time before the reform: 2.780 (hour)

badminton men's singles final of the London 2012 Olympic Games for example (http://data.2012.163.com/match/live / BDM001101.html) shown in the following TABLE 3:

According to the time index model, the ratio of Lin Dan and Lee Chong Wei winning the continuous i round balls in three games in the total score in is listed and calculated in TABLE 4:

By comparing the total match time, for the same game the total time before the reform is 1.9 times of that after the reform. Overlong playing time will increase the risk of injuries of athletes, and will also make the audience tired.

CONCLUSIONS

No matter for what kind of game system program, there is no absolute good or bad, but only relatively suitable and not suitable; from the above comparative analysis of contingency and intensity we can find that: The contingency using the best of five games for 15 points system is about 20% higher than that of best of five games for 21 points system; the increase of contingency improves the ornamental value of the badminton game, which gains richer suspense on the tournament, but excessive contingency makes the game lose too much athletic meaning.

According to the results of gray correlation model analysis, the contingency using the best of five games for 15 points system is very big; in the major international badminton competitions we should avoid using the program. The contingency using four wins in seven innings for 15 points system is roughly equal to that of best of five games for 21 points system, which is more reasonable competition system and can reduce injuries and improve enthusiasm for athletes to the greatest extent.

Due to the cancellation of side-out scoring system can greatly shorten the total time of the game significantly, thus in the organization of major events the badminton committee can more calmly make tournament arrangements, meanwhile viewers can watch more exciting badminton tournament, and then the badminton can get promotion.

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