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Research Article

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AHP-based tennis service technical evaluation consistency test

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ABSTRACT

The paper analyzes tennis players' techniques, it extracts comprehensive evaluation players' tennis techniques two main indicators and their corresponding indicators eleven small indicators, applies AHP to establish hierarchical structure, and for the structure, it applies paired comparison method to construct judgment matrix, on this basis it introduces overall consistency test model. Apply AHP method to state athlete sports ability, meanwhile it designs judgment matrix weight algorithm and overall consistency test algorithm, realizes four world excellent tennis players' actual parameters AHP analysis and gets the four players' service techniques merits and passes consistency test.

Key words: Tennis service technique, judgment matrix, consistency test, AHP algorithm

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INTRODUCTION

Since Li Na won the Australian Open, Chinese tennis has further ranked among the top nations in world sports. Tennis players sports ability is a kind of sports that comprehensive reflected by age, sports flexibility, playing techniques, psychological qualities [1-3]. Now tennis players' technical evaluation is indispensible in sports training, and evaluation ways for each kind of techniques also apply more mathematical theories, and abandons subjective uncertainness. Service is crucial to tennis, a good service can master tennis rhythm so that let opponent to get caught in passive situations [4-8]. In service technical evaluation research, thousands of people have made lots of researches, and got some result, these evaluation methods have been applied in practice which makes considerable real description on tennis techniques [9-12]. Among them, Wu Qiang (2009) in researching US Open Federer tennis techniques, he got that ordinary times training should focus on tennis players' techniques, tactics, psychology and others comprehensive development, and should pay more attention to psychological qualities training when playing the games [13-16]. Lin Chu-Hui and others established fuzzy mathematics evaluation model to make quantitative evaluation on tennis techniques each indicator, which provided feasible mathematics methods for players' selection. Zhou Jie in master thesis, he used world excellent men's tennis players technical statistics to make analysis, he thought the key to win in the field for tennis players is increasing winners and reduce unforced errors [5].

The paper analyzes tennis service techniques relative statistical data, establishes relative indicators construction hierarchical structure, by calculating each indicator weight, applying analytic hierarchy process mathematical model to establish tennis service technical evaluation model, it realizes service technical quantitative evaluation.

TENNIS SERVICE TECHNICAL EVALUATION AHP MODEL ESTABLISHMENTS

A complicated problem is composed of lots of branch problems, AHP makes methodize combing on complicated influence factors, and makes clear about these factors' primary and secondary as well as hierarchical structure, it further makes paired comparison with every primary and secondary factors and calculate their weights, finally analyzes and gets each part priority. In addition, AHP method can adopt subjectivity to construct judgment matrix and use objective values to make final evaluation measuring. Objectively, it requires subjective evaluation should conform to actual test evaluation consistency that weakens subjective randomness, increases subjective evaluation

rationality and accuracy. In the following, it states AHP analysis steps, sports ability hierarchical structure establishment, sports ability judgment matrix establishment and algorithm designing as well as consistency test algorithm designing principles and methods.

AHP analysis steps

Apply analytic hierarchy process to solve problems need to establish indicators logic relations, AHP analysis includes four steps, as Figure 1.

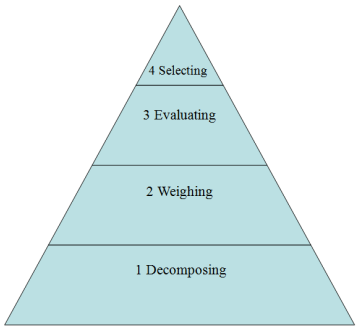

Figure 1: AHP analysis four steps

In Figure 1, it represents decompose overall system into a serious of small parts, as the paper tennis service technical ability; Step-2 represents weight all small parts after system decomposing; Step-3 represents each small parts to athlete player sports ability total contribution ability's evaluation; Step-4 represents obtain judgment result according to different players' each small parts to tennis techniques contribution ability strong and weak.

Sports ability hierarchical structure establishment

When AHP method researches on problems, it should divide problems into several layers according to the problems' each factor causal relationship, which is called hierarchy. Relative simple problems usually can be divided into three layers: target layer (tennis techniques), criterion layer (attack technique, defense technique) and measure layer (four athletes). The paper researched problems are relative complex that totally divides into four layers, top layer is target layer and called O layer for short that is tennis technique; medium layer is criterion layer that calls C layer for short, which divides into two layers that are respectively two main indicators C1layer and its corresponding sub section content C2 layer, bottom layer is measure layer that calls P layer for short, which are four players. As Figure 2, it shows the hierarchical structural graph.

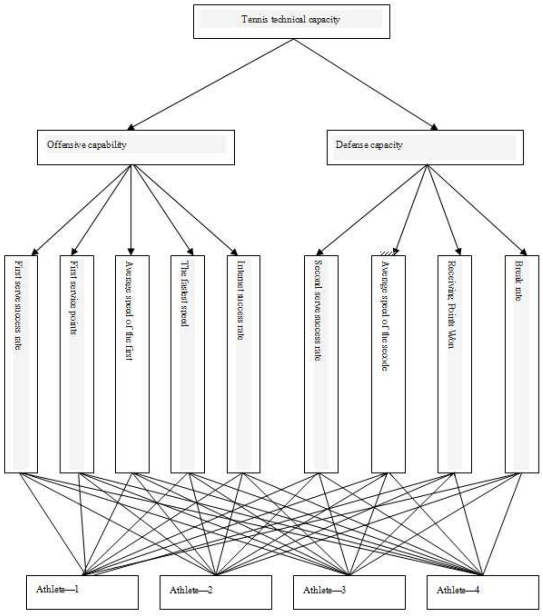

Figure 2: Hierarchical structure graph

Evaluation model establishment and algorithm design

Definition 1: The first layer and second layer weight expression is as formula (1) show:

$$w_1 + w_2 = 1 \tag{1}$$

In formula (1), w_1 represents attack technique to tennis techniques contribution weight, w_2 represents defense technique to tennis techniques contribution weight.

Definition 2: The second layer and the third layer weight expression are as formula (2) show:

$$\begin{cases} w_{11} + w_{12} + w_{13} + w_{14} + w_{15} = 1 \\ w_{21} + w_{22} + w_{23} + w_{24} = 1 \end{cases} \tag{2}$$

In formula(2), $w_{11}, w_{12}, w_{13}, w_{14}, w_{15}$ respectively represent first service success rate, first service scoring rate, first service evaluation speed per hour, highest speed per hour and net success rate to attack ability contribution weight; $w_{21}, w_{22}, w_{23}, w_{24}$ Respectively represents second service scoring rate, second service average speed per hour, receiving scoring rate and breaking rate to defense technique contribution weight.

Judgment matrix establishment and each layer weight generating algorithm design

If compare n pieces of factors to one factor F influence size, generally adopt paired factor comparison method to establish judgment matrix. Set a_{ij} represents factor β_i and β_j to factor F influence size ratio, it can get judgment matrix R, in the paper, we set the second layer and the first layer judgment matrix to be R_1, element to be a_{ij}, factors to be α_i, α_j, factor to be F_1, and then it has as formula (3) showed judgment matrix R_1:

$$R_1 = \begin{bmatrix} F_1 & \alpha_1 & \alpha_2 & \alpha_3 & \alpha_4 \\ \alpha_1 & a_{11} & a_{12} & a_{13} & a_{14} \\ \alpha_2 & a_{21} & a_{22} & a_{23} & a_{24} \\ \alpha_3 & a_{31} & a_{32} & a_{33} & a_{34} \\ \alpha_4 & a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \tag{3}$$

In formula(3), F_1 represents factor sports ability, $\alpha_1, \alpha_2, \alpha_3, \alpha_4$ represent body shape factor, body function factor, psychological quality factor and sport quality factor, a_{ij} represents factor α_i and factor α_j to factor F_1 influence size. a_{ij} size defining, we generally adopt 1～9 proportional scale to impact weight, as Figure 3 show.

Table 1: 1～9 scale table

Scale a_{ij}	Definition
1	factor i and factor j have equal importance
3	factor i is slightly more important than factor j
5	factor i is relative more important than factor j
7	factor i is extremely more important than factor j
9	factor i is absolute more important than factor j
2,4,6,8	Indicates middle state corresponding scale value of above judgments
Reciprocal	If compare factor i with factor j, it gets judgment value as $a_{ji} = 1/a_{ij}$, $a_{ii} = 1$

At first, solve judgment matrix, according to above principle, reference 1-9 scale setting, and according to experts' experiences and refer to lots of documents, it gets paired comparison matrix.

Consistency test algorithm design

Due to objective things complex and people recognition diversity decision, in judgment matrix construction process, it will not let $a_{ij} \bullet a_{jk} = a_{ik}$ seriously to be true, so when calculate weight vector under single criterion, it should

also make consistency test. Take matrix R_1 as an example to do algorithm design, as following show:

Step-1: It solves vector $\vec{a}=(a_1,a_2,a_3,a_4)$ and vector $\vec{w}=(w_1,w_2,w_3,w_4)$;

Step-2: It solves matrix R_1 maximum feature value $\lambda_{\max}$, its computational method is as formula(4)show:

$$\lambda_{\max}=\vec{a}\bullet\vec{w}=\begin{pmatrix}a_1 & a_2 & a_3 & a_4\end{pmatrix}\begin{pmatrix}w_1\\w_2\\w_3\\w_4\end{pmatrix} \tag{4}$$

Step-3: Calculate consistency indicator CI, its computational method is as formula (5)show:

$$CI=\frac{\lambda_{\max}-n}{n-1}=\frac{\lambda_{\max}}{3}-\frac{4}{3} \tag{5}$$

In formula(5), n represents number of criterion, which is also the number of factors, so to R_1 matrix $n=4$

Step-4: Calculate consistency ratio CR, its computational method is as formula(6)show:

$$CR=\frac{CI}{RI} \tag{6}$$

In formula(6), RI represents Random Consistency Index value, as Table 2 show.

Table 2: Consistency test

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

So formula (6) can be revised into $CR=\frac{\lambda_{\max}-4}{3\times0.9}$

Step-5: Consistency judgment

When $CR>0.1$, judgment result outputs “present obvious inconsistence”, when $CR<0.1$, judgment result outputs “ present considerable consistence”.

COMPREHENSIVE EVALUATION ESTABLISHMENT

By above each indicator weight calculation, it can get evaluation model: $y=\sum_{i=1}^{n}w_i x_i$

Among them, w_i, x_i, respectively represent second indicator weight and second grade indicator.

TENNIS TECHNICAL EVALUATION APPLICATION EXAMPLE

Judgment matrix and consistency test

According to experts research and interview, experts and professors data, it makes paired comparison on indicators with 1～9 grades scale method, it gets indicator judgment matrix as following table.

$$R=\begin{pmatrix} 1 & 1/2 & 5 & 6 & 6 & 7 & 4 & 2 & 8 \\ 2 & 1 & 6 & 5 & 7 & 8 & 4 & 3 & 9 \\ 1/5 & 1/6 & 1 & 1/5 & 3 & 5 & 1/5 & 1/6 & 6 \\ 1/6 & 1/5 & 5 & 1 & 4 & 3 & 1/2 & 1/5 & 1 \\ 1/6 & 1/7 & 1/3 & 1/4 & 1 & 2 & 1/4 & 1/6 & 5 \\ 1/7 & 1/8 & 1/5 & 1/3 & 1/2 & 1 & 1/6 & 1/3 & 4 \\ 1/4 & 1/4 & 5 & 2 & 4 & 6 & 1 & 1/4 & 7 \\ 1/2 & 1/3 & 6 & 5 & 6 & 3 & 4 & 1 & 8 \\ 1/8 & 1/9 & 1/6 & 1/7 & 1/5 & 1/4 & 1/7 & 1/8 & 1 \end{pmatrix}$$

It can get by MAtlab computing: $\lambda_{\max} = 3.04$, $CI = 0.019$

Make consistency test on judgment matrix, it gets: $CR = CI / RI = 0.019 / 0.52 = 0.04 < 0.10$

It passes consistency test that shows objective weight judgment can be done.

Weight calculation and list

Each indicator weight calculation can accord formula: $$w_i = \sum_{j=1}^{n} a_{ij} / n$$

By calculating, it gets each indicator weight as following Table 3 show.

Table 3: Weight table

First grade indicator	Weight	Second grade indicator	Weight
Attack technique	0.466	First service success rate	0.198
		First service scoring rate	0.226
		First service evaluation speed per hour	0.080
		Highest speed per hour	0.106
		Net success rate	0.047
Defense technique	0.657	Second service scoring rate	0.034
		Second service average speed per hour	0.129
		Receiving scoring rate	0.170
		Breaking rate	0.113

Men's four main tennis competitions champions and opponents fighting in 2012, each indicator relative data statistics is as following Table 4 show:

Table 4: Indicator data table

Indicator	Djokovic	Federer	Murray	Nadal
First service success rate	60.71	66.71	60.71	62.86
First service scoring rate	73.71	79.14	74.57	77.14
First service evaluation speed per hour	188.29	184.8	178.14	183.29
Highest speed per hour	201.14	203.7	212.86	203.14
Net success rate	70.86	72.71	70.29	75.71
Second service scoring rate	59.14	59.43	51.71	61
Second service average speed per hour	150.86	157.7	136.14	145.43
Receiving scoring rate	51.43	44.86	42.86	50.29
Breaking rate	53	47.57	41.86	61.14

Evaluation result

Input four tennis players' indicator data into analytic hierarchy process evaluation model, calculate scores as following Table 5:

Table 5: Comprehensive evaluation result table

Name	Djokovic	Federer	Murray	Nadal
Score	104.60	106.25	100.33	105.93

The paper uses simple analytic hierarchy process comprehensive evaluation model to evaluate four world excellent tennis players, and then gets the four ranking are successively as: Federer, Nadal, Djokovic and Murray.

CONCLUSION

The paper applies analytic hierarchy process method into tennis technical evaluation, and then it establishes subjective evaluation and objective technical indicators combative mathematical model, scientific and reasonable solves tennis techniques each indicator weight problems that provide easy and feasible methods for tennis talents selection. Meanwhile, it provides objective methods for objective and reasonable evaluating a tennis player technique, and gets rid of single relying on scores to evaluate players or referees provided subjective evaluation.

Meanwhile, different players has different abilities in tennis techniques' each indicator, compares with indicator weights, it can provide certain evidence for tennis players' training, such as, it should put emphasis on training tennis players larger weights techniques so that rapidly improve tennis.

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