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Empirical research on sprint ability based on matlab and analytic hierarchy process

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ABSTRACT

In this paper, sprint athletic performance can be volatile and it is difficult to quantify the real strength of the athletes. After the studies and long-term practice, the traditional research methods have been improved and more scientific and reasonable evaluation index system of sprint athletic ability has been established. According to AHP, we establish quantitative model; using Matlab, we solve a large number of matrix calculation problems in the AHP model. At the mean time of satisfying the high precision and efficiency, the model can be easily modified and adjusted. Finally, after the empirical evaluation, the results are scientific, reasonable and can be effectively solve the overall quantification problem of the comprehensive strength of sprinters. This achievement has a high application value for the design of the targeted training programs to improve sprint performance.

KEYWORDS

Analytic hierarchy process;
Analytic hierarchy process;
Sports evaluation.

INTRODUCTION

Although we have found a lot of factors influencing the sprint performance after the research for may years, because these factors are multifaceted and the relationship with the actual performance is only correlated, the majority of researches are the qualitative researches, and accurate quantitative analysis are very difficult to implement. So it requires an objective and accurate evaluation exercise capacity.

After the establishment of the sprinting ability evaluation model by using of AHP, due to a large number of the matrix calculation caused by AHP index weight calculation and judgment matrix consistency test, the use of computer is the undoubtedly the best choice when the traditional manual calculation is difficult to meet the efficiency and requirements of accuracy. Based on the computing processing power of scientific computing platform Matlab from the well-known American Math Works, we use of M-language programming to realize the combination of AHP and computer-assisted decision-making and implement the solution of the important parameters of AHP model and consistency test, which can not only provide the computer-aided decision-making for the scientific evaluation of sprint ability, but also provide a new way of thinking for the mathematical methods and computer-aided applications in the field of sports training.

OBJECTS AND METHOD

Research object

The empirical object of the study is 40 male sophomores in our university, including 20 specialized sprinting students and 20 non-professional students, aiming at when conducting longitudinal studies and doing horizontal comparison at the same time. We will testify whether this method is scientific and universal or not in the field of the evaluation sprint capacity based on objective data.

Research method

In this paper, we use the Analytic Hierarchy Process (AHP). The structure is as Figure 1. Layer A is the target Layer; Layer B is first grade index layer; Layer C is second grade index layer.

The establishment of the index system strives to select the easily measured, high sensible, and content-rich indicators from many indicators which can influence athletic ability. This indicator selection methods used are the literature method and expert questionnaire method. We will study the factors that affect sprint performance and read a lot of literatures. Considering the research results from Hu Xiaofang and Yuan Yunping, and the suggestions from many experts who are engaged in sprinter training and teaching for a long time, we improve the indicator system created by the predecessors and select the indicators. Finally we obtain the evaluation indicator system mentioned in this article. The system includes quantitative indicators and qualitative indicators which are body shape, physiology, sports quality, coaching evaluation, totaling five first grade indicators and 17 secondary indicators. The indicators are shown in TABLE 1.

After the establishment of the evaluation indicator system, the weights of the indicators should be determined. First, the scaling exponent should be determined. The weight calculation of AHP has many different scaling exponents, and the most common method is 1ˆÿ9 and its reciprocal raised by Satty. This method has many shortcomings such as subjectivity and low accuracy of the values. So in this article, we use one new scaling exponent which is $\ln\left(\frac{9}{9}e\right) \sim \ln\left(\frac{17}{1}e\right)$. The weight calculation results by using this scaling exponent are more scientific and reliable. The comparison between this standard and the traditional $1 \sim 9$ evaluation standard is as TABLE 2.

a_{ij} represents the relative importance of the two elements; construct the relative importance judgment matrix A to indicate the result of each comparison.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (a_{ii} = 1,\ a_{ij} > 0,\ a_{ji} = \frac{1}{a_{ij}}) \qquad (1)$$

We have sent out 74 indicator weight investigation forms and received 70 feedbacks including 20 senior coaches, 30 professors and associate professors who have been engaged in the track and field training for years. Considering the opinions of the experts, the judgment matrixes have been obtained.

$$A = \begin{pmatrix} 1.000 & 1.693 & 1.223 & 2.253 \\ 0.591 & 1.000 & 0.689 & 1.693 \\ 0.811 & 1.452 & 1.000 & 1.956 \\ 0.444 & 0.591 & 0.511 & 1.000 \end{pmatrix} \quad B_1 = \begin{pmatrix} 1.000 & 0.325 & 0.444 & 0.383 & 0.444 & 0.325 \\ 3.079 & 1.000 & 1.452 & 1.233 & 1.452 & 0.811 \\ 2.253 & 0.689 & 1.000 & 0.811 & 1.000 & 0.689 \\ 2.609 & 0.811 & 1.233 & 1.000 & 1.233 & 0.811 \\ 2.253 & 0.689 & 1.000 & 0.811 & 1.000 & 0.591 \\ 3.079 & 1.233 & 1.452 & 1.233 & 1.693 & 1.000 \end{pmatrix}$$

$$B_2 = \begin{pmatrix} 1.000 & 0.689 & 0.325 \\ 1.452 & 1.000 & 0.444 \\ 3.079 & 2.253 & 1.000 \end{pmatrix} \quad B_3 = \begin{pmatrix} 1.000 & 1.452 & 1.233 & 2.253 \\ 0.689 & 1.000 & 0.811 & 1.693 \\ 0.811 & 1.233 & 1.000 & 1.956 \\ 0.444 & 0.591 & 0.511 & 1.000 \end{pmatrix} \quad B_4 = \begin{pmatrix} 1.000 & 3.833 & 1.693 & 1.956 \\ 0.261 & 1.000 & 0.325 & 0.325 \\ 0.591 & 3.079 & 1.000 & 1.000 \\ 0.511 & 3.079 & 1.000 & 1.000 \end{pmatrix}$$ 。

Using the above judgment matrix A, we can get the indicator weights in the indicator layer B and these weights construct the importance of the indicators in Layer. In the same way, we can get the weights of each indicator in Layer to the indicators in Layer. At last we can get the comprehensive weight of the indicators in Layer and Layer to the target layer. The common weight calculation methods are average method and square root method. In this article the square root method has been adopted which means to multiply all the factors in the judgment matrix and then seek $1/n$ power.

$$w_i = \left(\prod_{j=1}^{n} c_{ij}\right)^{1/n}, \quad (i, j = 1, 2, \ldots, n) \qquad (2)$$

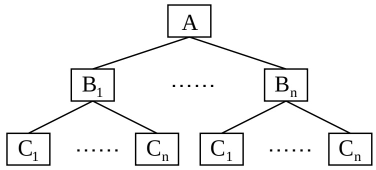

Figure 1 : AHP structure model

TABLE 1: Sprint capacity assessment indicators

Target Layer A	First Grade Indicator B	Secondary Indicator C
Sprint Capacity Evaluation	Body Shape B1	Age C1 Height C2 Quetelet Index (Weight/Height×1000) (g/cm) C3 Lower Extremity/Height ×100% C4 Thigh Length /Shin Length ×100% C5 Ankle Girth/Tendon Length ×100% C6
	Physiology B2	Heart Rate (Frequency/m) C7 FVC/weight (ml/kg) C8 Time of the Acoustic Response (ms) C9
	Sports Quality B3	60m Running Race (s) C10 Standing Triple Jump (m) C11 Step Frequency (Step/s) C12 After Throwing Shot Put (m) C13
	Coaching Evaluation B4	Physical Coordination C14 Acceptance Ability C15 Running Posture C16 Willpower C17

TABLE 2 : Comparison between two scaling exponents

Scaling Exponents	1~9	$\ln\left(\frac{9}{9}e\right) \sim \ln\left(\frac{17}{1}e\right)$
Equally Important	1	$\ln\left(\frac{9}{9}e\right)=1.000$
Tiny Important	2	$\ln\left(\frac{10}{8}e\right)=1.223$
Slightly Important	3	$\ln\left(\frac{11}{7}e\right)=1.452$
More Important	4	$\ln\left(\frac{12}{6}e\right)=1.693$
Obviously Important	5	$\ln\left(\frac{13}{5}e\right)=1.956$
Very Important	6	$\ln\left(\frac{14}{4}e\right)=2.253$
Strongly Important	7	$\ln\left(\frac{15}{3}e\right)=2.609$
Extremely Important	8	$\ln\left(\frac{16}{2}e\right)=3.079$
Most Important	9	$\ln\left(\frac{17}{1}e\right)=3.833$

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (4)$$

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{w_i} \quad (5)$$

$$CR = \frac{CI}{RI} \quad (6)$$

CI is the general consistency indicator. is the average random consistency indicator. When the exponent number is different, the value is shown in TABLE 3. is the maximum eigenvalue of the judgment matrix. When the value of is smaller, the judgment matrix is more effective. The usual standard is . On the contrary, when the

TABLE 3 : Values of average random consistency indicators

Exponent Number	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.46
Exponent Number	10	11	12	13	14	15			
RI	1.49	1.52	1.54	1.56	1.58	1.59			

Then normalize and get weight sub-value

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (3)$$

Weight vector is $W=(W_1,W_2,\ldots,W_n)^t$

In order to ensure the validity of the above judgment matrix and weights, we should implement the consistency test, because the relative importance of each indicator is determined by the questionnaire, scores made by the experts and statistics. When the degrees of importance are close, we should make consistency test. The usual test method is to use CR value which is the random consistency ratio. The formula is as below,

value of is bigger, we need to adjust the judgment matrix.

The indicator weight determined by the judgment matrix and the consistency test can be realized by Matlab. The process can be shown in Figure 2 as below.

According to the above judgment matrix and formula, compile and calculate the weight vectors of the indicators. The maximum eigenvalues and Matlab program implementing the consistency test to the judgment matrixes are as follows.

From the above result, the first grade indicator

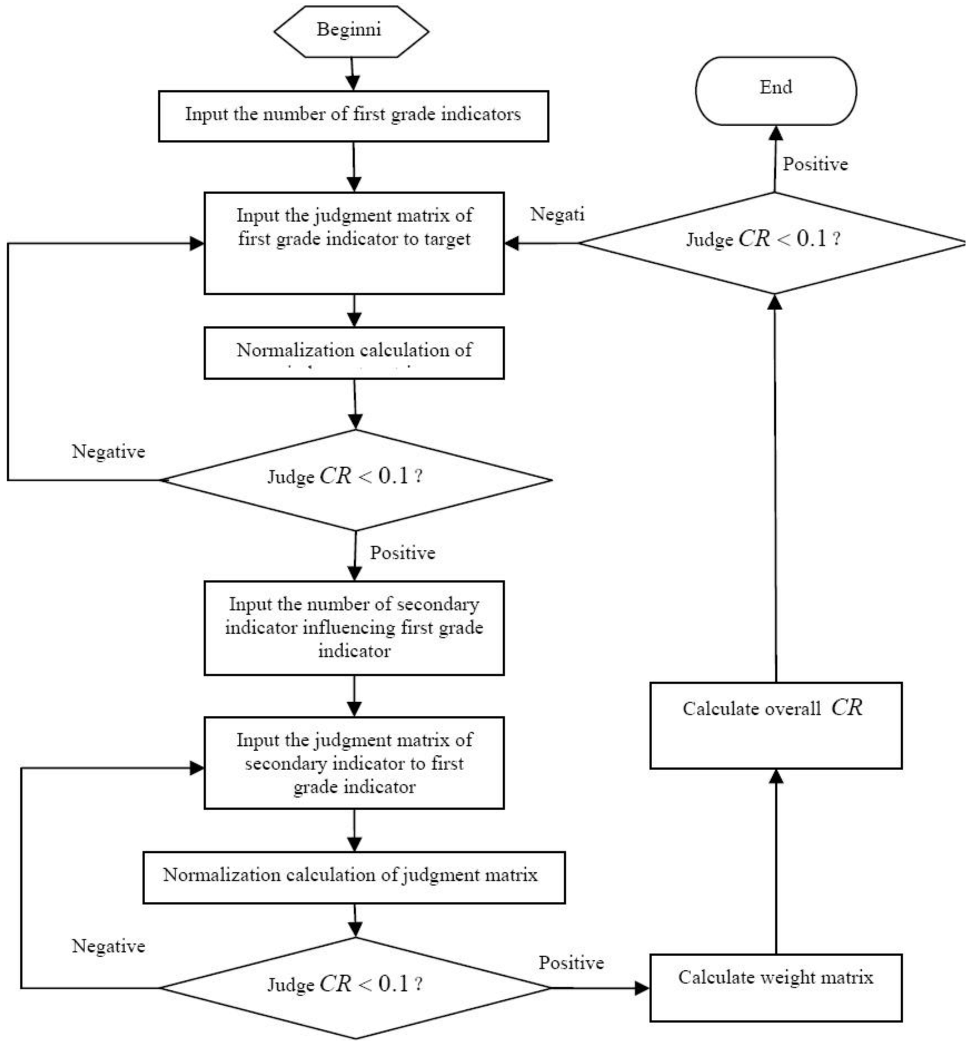

Figure 2 : Matlab Processing flow based on AHP

weight vector is and the secondary indicator weight vectoris $W_1 = (0.07, 0.21, 0.15, 0.18, 0.15, 0.24)^T$; $W_2 = (0.18, 0.26, 0.56)^T$; $W_3 = (0.34, 0.24, 0.28, 0.14)^T$; $W_4 = (0.41, 0.09, 0.25, 0.25)^T$

When obtaining the weight vectors, the maximum eigenvalue and random consistency indicator can be got. From the result, the values of are smaller than 0.1, which means that the all the judgment matrixes have good consistency. This can greatly reflect the relative importance among the indicators. We can know that the weights of the indicators are scientific and reasonable which can reflect the importance the opinions from experts and the indicators to the sprinters ability.

By weighted summing the 4 first grade indicator weights and the partial weights of 17 secondary indicators, the overall comprehensive weights of all the secondary indicators can be got. It can be shown in TABLE 4.

Combining the evaluation indicator system constructed above, the judgment matrix tested to satisfy the consistency and the partial and comprehensive weights of the indicators, we can calculate the comprehensive indicators of all the sprinters, realize the quantization of performance of the sprinters and evaluate and analyze the sprinters.

This empirical research selects 40 male sophomores, including 20 from PE major and 20 from non-PE major at the age of 19-21. They have the best performance in the 100m sprint. The indicators are from the yearly evaluation which can be shown in TABLE 5. Only 10 students' data available, including data from 5 PE major students and 5 non-PE students.

The calculation formula of sprinter sport capacity

TABLE 4 : Comprehensive quality evaluation indicator weights of sprint

First Grade Indicator	Secondary Indicators	Weights	Third Grade Indicators	Partial Weights	Comprehensive Weights
A	B1	0.35	C1	0.07	0.025
			C2	0.21	0.074
			C3	0.15	0.053
			C4	0.18	0.063
			C5	0.15	0.053
			C6	0.24	0.084
	B2	0.22	C7	0.18	0.040
			C8	0.26	0.057
			C9	0.56	0.123
	B3	0.29	C10	0.34	0.099
			C11	0.24	0.070
			C12	0.28	0.081
			C13	0.14	0.041
	B4	0.14	C14	0.41	0.057
			C15	0.09	0.013
			C16	0.25	0.021
			C17	0.25	0.019

TABLE 5 : Original data of Evaluation indicators

Serial Number	1	2	3	4	5	6	7	8	9	10
C1	21	20	21	21	20	20	19	20	19	20
C2	181	175	172	177	168	170	163	167	169	170
C3	382	395	380	403	410	389	375	384	370	381
C4	53.2	52.8	51.3	51.5	52.1	50.9	50.4	51.2	50.2	51.3
C5	70.2	71.5	71.4	70.5	69.8	67.6	69.6	70.1	68.5	67.4
C6	102	104	101	99	100	101	95	97	94	97
C7	73	74	80	75	78	81	85	80	78	82
C8	98	100	95	97	102	105	97	95	90	77
C9	100	95	98	110	102	95	120	118	117	121
C10	7.38	7.24	7.40	7.31	7.30	7.10	7.09	7.10	7.15	7.13
C11	9.21	9.15	9.05	8.90	9.14	8.72	8.65	8.54	8.70	8.82
C12	4.5	4.6	4.7	4.3	4.2	4.0	3.9	4.2	4.1	4.0
C13	14.5	14.0	14.3	13.8	13.5	12.8	12.4	12.9	13.1	12.8
C14	79	84	74	71	68	75	74	58	74	68
C15	77	78	75	75	70	73	73	75	55	56
C16	75	77	71	80	68	70	76	57	67	60
C17	71	74	73	75	75	69	67	58	46	45

indicator is as follows,

$$A_I = \sum_{i=1}^{n} x_{ij} w_j \tag{7}$$

In the formula, A_I is the comprehensive quality indicator; x_{ij} ($0 \le x_{ij} \le 1$) represents the evaluation result of the th indicator of the th sample and it is a standard data. For the value of each indicator, the indicators that can be quantified can be standardized and the impact of the dimension can be eliminated; the indicators that can't be quantified can be standardized by averaging the scores made by the experts. The standardization is implemented by formulas (8), (9), (10) and (11). First define the average value and standard deviation of the j th indicator in the f samples.

$$x_j = \frac{1}{f}\sum_{i=1}^{f} x_{ij} \tag{8}$$

$$s_j = \sqrt{\sum_{i=1}^{f} (x_{ij} - x_j)^2} \tag{9}$$

Then standardize the original data.

$$x_{ij}' = (x_{ij} - x_j)/s_j \quad (10)$$

We use extreme value standardization formula and make the standardized data map in , which is as below,

$$x_{ij} = \frac{x_{ij}' - x_{j\min}'}{x_{j\max}' - x_{j\min}'} \quad (11)$$

In the formula, $x_{j\min}'$ and $x_{j\max}'$ respectively represent the minimum and maximum in $x_{1j}', x_{2j}' \ldots x_{fj}'$; x_{ij} is the standardized result of the th indicator of the th sample. By using the above formula, we can get the standardized results of all the indicators which is partially listed in TABLE 6.

TABLE 6 : Standardized results of the sample data (Part)

Serial Number	1	2	3	4	5	6	7	8	9	10
C1	0.83	0.84	0.70	0.87	0.68	0.69	0.73	0.68	0.69	0.60
C2	0.78	0.62	0.76	0.69	0.52	0.50	0.62	0.61	0.58	0.60
C3	0.69	0.73	0.60	0.69	0.61	0.65	0.58	0.60	0.69	0.64
C4	0.63	0.69	0.60	0.75	0.44	0.49	0.47	0.48	0.44	0.40
C5	0.65	0.58	0.60	0.69	0.60	0.41	0.40	0.42	0.38	0.37
C6	0.70	0.75	0.65	0.56	0.53	0.69	0.60	0.61	0.69	0.74
C7	0.53	0.59	0.57	0.70	0.67	0.64	0.71	0.63	0.61	0.58
C8	0.77	0.84	0.80	0.69	0.60	0.70	0.65	0.77	0.72	0.60
C9	0.64	0.63	0.61	0.58	0.60	0.66	0.60	0.65	0.61	0.65
C10	0.81	0.87	0.72	0.80	0.66	0.65	0.62	0.59	0.74	0.67
C11	0.78	0.85	0.81	0.85	0.74	0.73	0.70	0.7	0.64	0.71
C12	0.80	0.89	0.74	0.87	0.83	0.79	0.80	0.65	0.65	0.68
C13	0.83	0.80	0.70	0.86	0.80	0.70	0.69	0.61	0.62	0.64
C14	0.75	0.80	0.70	0.67	0.64	0.71	0.70	0.54	0.70	0.64
C15	0.71	0.72	0.69	0.69	0.65	0.68	0.68	0.70	0.50	0.51
C16	0.69	0.71	0.65	0.74	0.62	0.64	0.70	0.51	0.61	0.54
C17	0.66	0.69	0.68	0.70	0.70	0.64	0.62	0.53	0.42	0.41

According to the formula of sprint ability and the indicator weights, we can get:

$$A_I = \sum_{i=1}^{17} x_{ij} w_j = 0.025d_1 + 0.074d_2 + 0.053d_3 + \cdots + 0.019d_{17}$$

Using the data in TABLE 6, we can get the evaluation results of sprint ability of each sample which can be seen in TABLE 7.

ANALYSIS OF RESULT

From the indicator weights, we can find that the sport quality and body shape are the main influential factors. Height, the ratio of ankle girth and tendon length, weight and the length of lower extremity have most impact on the physical quality; in the aspect of the sport quality, 60m race can reflect the speedup ability of the players, which has the most impact, followed by step frequency and standing triple jump. These two indicators, the crucial influential factors, have connection with the strength of the lower extremity and the frequency. Besides, the times of response and body coordination are also the important factors of the sprint ability. These results are valuable for the player selection, training and performance improvement.

By contrasting the measured results of sprint ability from this mode with the annual bests 100m performance; we can find that the sprint ability evaluation system in this article can well reflect the level of athletic ability. The results are objective and accurate. The quantified results can effectively avoid the volatility caused by the instability and the performance. Through the comparison between the PE students and the non- PE students, the model can effectively identify and quantify the impact of quality improvement on the sprint capacity. It has a wide applicability.

TABLE 7 : Comparison between model evaluation result and yearly top achievements

Serial Number	1	2	3	4	5	6	7	8	9	10
Evaluation Value	0.722	0.744	0.683	0.719	0.633	0.646	0.632	0.606	0.620	0.610
Measured Value（s）	11.58	11.20	11.72	11.65	12.03	12.64	12.79	13.23	13.02	12.41

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CONCLUSIONS

In this article, we first establish a scientific and reasonable sprint comprehensive ability evaluation indication and then through study and practice, we improve the traditional sport ability research method, establishing a new and more scientific sprint ability evaluation indication system. The sprint ability quantization model based on AHP has been established. We use Matlab software to calculate the weight and implement the consistency test, which can make the model more accurate and efficient. When the model is inappropriate, we can adjust and revise. After the empirical test, we can evaluate the comprehensive ability of the sprinters objectively and accurately. It is valuable to the draft of the targeted training plan, the improvement of the performance and scientific player selection. It is also one important attempt combining the computer-aided processing with the mathematical method, which can provide a way for the future research.

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