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Statistical analysis of sprint athletic ability evaluation index system based on AHP model

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ABSTRACT

Aiming at the problem that sprint athletic performance can be volatile and it is difficult to quantify the real strength of athletes, this paper, by a large number of studies and long-term practice, daringly improves the traditional exercise capacity research methods, establishes new, more scientific and reasonable sprint athletic ability evaluation index system and establishes quantitative model using Analytic Hierarchy Process. After empirical test the results are scientific and reasonable, effectively solve the overall strength quantification problem of sprinters; the results have a high application value for the development of targeted training programs, the improvement of sprint performance and scientific selection.
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KEYWORDS

Analytic hierarchy process;
Exercise evaluation;
Sprinting ability.

INTRODUCTION

With the increasingly development of modern athletics and scientifically sound of training level, the requirement of the athlete's athletic ability needs to be improved. In order to improve athletic performance, we need to start from athletic ability. Without good athletic ability, even with better training method, it is difficult to obtain excellent results. And research on exercise capacity is also very important in the Sprinter selection stage. Due to the body's own characteristics, each person's potential in the sport is different. Early detection of potential talent, scientific and accurate evaluation of its athletic ability can avoid the enormous waste in the human, material and financial aspects, which is direction that the entire sports industry has been working for.

On the basis of a number of related research, this paper combines with practical experience, uses AHP to study factors affecting sprint ability, establishes mathematical evaluation model, not takes the actual best score as a standard to measure the sprint ability, but judge the sprint comprehensive ability with the affect of all aspects of quality and factors, excludes results volatility brought by a variety of destabilizing factors, and hopes to get an objective, scientific and accurate capacity assessment.

RESEARCH METHOD AND PROCESS

Research object

40 sophomore boys, there are 20 students of sports specialty in professional sprint training, and 20 non-

sports majors.

Research method

This paper uses the analytic hierarchy process (AHP), the method is proposed by the famous American operation researcher Saaty TL in the 1970s; After forty years of development and improvement, it has now become a very common analysis method in system science. Its hierarchical structure is shown in Figure 1:

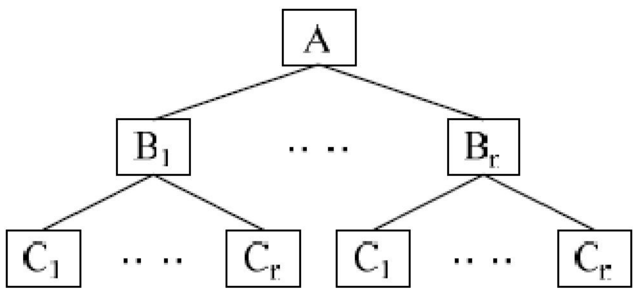

Figure 1 : AHP hierarchical structure model

Where, layer A is the target layer, layer B is the first level index layer, and layer C is the secondary index layer.

This index selection method used in this paper is the literature and expert questionnaire, conduct a comprehensive study on the factors that affect sprint performance and read a lot of literature, many previous studies have found some indicators that have impact on sprint performance. It seeks many expert opinions that have long been engaged in spring training, improves the previous established index system, conducts trade-offs of various indicators, and ultimately determines the evaluation index system of this article. There are both qualitative and quantitative indicators including body shape, physiology, sports quality, coach evaluation, with a total of five first level indicators and 17 secondary indicators, as shown in TABLE 1:

Research process

After evaluation index system is established, we need to determine the weight of each index. First, determine the scale, the weight calculation of AHP has multiple different scales. The most commonly used is the classic 1~9 and scale method of its countdown raised by SATTY. This scaling method has strong subjective, low value accuracy and other defects. This paper selects a new scale, namely $\ln\left(\frac{9}{9}e\right) \sim \ln\left(\frac{17}{1}e\right)$, the weight calculation results under this scale is more scientific and reliable than several other scales. The comparison with the traditional 1~9 scoring criteria is in TABLE 2:

TABLE 1 : Sprint capacity evaluation system

Target layer A	First level index B	Secondary index C
Sprint capacity evaluation	Body shape B1	Age C1
		Height C2
		Quetlet index(weight/height×1000)(g/cm)C3
		Lower limbs length/height ×100% C4
		Thigh length/calf length ×100% C5
		Ankle circumference/tendo calcaneus length ×100% C6
	Physiological function B2	Heart rate(time/m) C7
		Vital capacity/weight (ml/kg) C8
		Sound reaction time(ms) C9
	Sport quality B3	60m run(s) C10
		Standing triple jump(m) C11
		Stride frequency(step/s) C12
		Back throw shot(m) C13
	Coach evaluation B4	Physical coordination C14
		The receptivity ability C15
		Running posture C16
		Willpower C17

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TABLE 2 : Description comparison of two kinds of scales

Scale	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	$\ln\left(\frac{10}{8}e\right)=1.223$
Little 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	$\ln\left(\frac{14}{4}e\right)=2.253$
Highly important	7	$\ln\left(\frac{15}{3}e\right)=2.609$
Essentially important	8	$\ln\left(\frac{16}{2}e\right)=3.079$
Extremely important	9	$\ln\left(\frac{17}{1}e\right)=3.833$

Use a_{ij} to represent the relative importance degree of two selected elements, construct the relative importance degree judgment matrix A of each indicator to represent the comparison results of each group.

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Where $a_{ii}=1$, $a_{ij}>0$, and, $a_{ji}=\frac{1}{a_{ij}}$.

The index weight questionnaire in this paper are 74 parts and returned valid questionnaires are 70 parts; surveyed object includes 12 national coaches, 20 senior coaches, and 30 professors and associate professors long-term engaged in track and field projects training and teaching, construct judgment matrix combining with a number of expert opinions as follows:

$$A=\begin{pmatrix} 1.000 & 1.693 & 1.223 & 2.253 \\ 0.591 & 1.000 & 0.689 & 1.693 \\ 0.811 & 1.452 & 1.000 & 1.956 \\ 0.444 & 0.591 & 0.511 & 1.000 \end{pmatrix}$$

$$B_2=\begin{pmatrix} 1.000 & 0.325 & 0.444 & 0.383 & 0.444 & 0.325 \\ 3.079 & 1.000 & 1.452 & 1.233 & 1.452 & 0.811 \\ 2.253 & 0.689 & 1.000 & 0.811 & 1.000 & 0.689 \\ 2.609 & 0.811 & 1.233 & 1.000 & 1.233 & 0.811 \\ 2.253 & 0.689 & 1.000 & 0.811 & 1.000 & 0.591 \\ 3.079 & 1.233 & 1.452 & 1.233 & 1.693 & 1.000 \end{pmatrix}$$

$$B_2=\begin{pmatrix} 1.000 & 0.689 & 0.325 \\ 1.452 & 1.000 & 0.444 \\ 3.079 & 2.253 & 1.000 \end{pmatrix}$$

$$B_3=\begin{pmatrix} 1.000 & 1.452 & 1.233 & 2.253 \\ 0.689 & 1.000 & 0.811 & 1.693 \\ 0.811 & 1.233 & 1.000 & 1.956 \\ 0.444 & 0.591 & 0.511 & 1.000 \end{pmatrix}$$

$$B_4=\begin{pmatrix} 1.000 & 3.833 & 1.693 & 1.956 \\ 0.261 & 1.000 & 0.325 & 0.325 \\ 0.591 & 3.079 & 1.000 & 1.000 \\ 0.511 & 3.079 & 1.000 & 1.000 \end{pmatrix}.$$

Using the effective judgment matrix A obtained above, you can find the index weight of index layer B, and these weights constitute the importance degree of each index in layer B. Similarly, we can obtain the index weight of layer B to index layer C. Finally, find the comprehensive weight of layer B and layer C to the target layer. The commonly used calculation methods have mean method and square root method. We use the square root method. Conduct quadrature to the row elements in the judgment matrix, and then seek the power of $1/n$:

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

Rerunning normalization processing, get weighting coefficient:

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

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

From the above judgment matrix, the first layer index weight vector $W=(0.37,0.20,0.35,0.08)^T$ and the secondary index weight vector

$W_1=(0.06,0.21,0.16,0.19,0.15,0.23)^T$

$W_2=(0.18,0.24,0.58)^T$

$W_3=(0.33,0.24,0.28,0.15)^T$

$W_4=(0.42,0.08,0.26,0.24)^T$.

In order to ensure the validity of the judgment matrix and weight, we also need the consistency test, as shown in following formula:

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

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

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

Where CI is the general consistency index, RI is the average random consistency index. When the order is different, its value is shown in TABLE 3. Parameter $\lambda_{\max}$ is the maximum eigenvalue of the judgment matrix. When the calculated CR value is smaller, the judgment matrix is more effective. The usual standard is $CR \le 0.1$. Conversely, if the CR value is too large, you need to adjust the judgment matrix.

TABLE 3 : The values of average random consistency index

Order	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	1.45

Using the above formula (4), (5), (6) to conduct consistency test for each judgment matrix (take the judgment matrix for example), first calculate the maximum eigenvalue $\lambda_{\max}$:

$$AW = \begin{pmatrix} 1.000 & 1.693 & 1.000 & 3.383 \\ 0.591 & 1.000 & 0.591 & 2.609 \\ 1.000 & 1.693 & 1.000 & 3.833 \\ 0.261 & 0.383 & 0.261 & 1.000 \end{pmatrix} \begin{pmatrix} 0.33 \\ 0.20 \\ 0.35 \\ 0.08 \end{pmatrix} = \begin{pmatrix} 1.29 \\ 0.81 \\ 1.33 \\ 0.33 \end{pmatrix}$$

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{w_i} = \frac{1}{4}\left(\frac{1.29}{0.33}+\frac{0.81}{0.20}+\frac{1.33}{0.35}+\frac{0.33}{0.08}\right) = 3.97$$

$$CI = \frac{\lambda_{\max} - n}{n-1} = \frac{3.97-4}{3} = -0.0097$$

$$CR = \frac{CI}{RI} = \frac{-0.0097}{0.90} = -0.107$$

$CR = -0.107 < 0.1$, indicating that the individual judgment matrix is in good consistency. Similarly, the third layer indicators of layer C and the indicators of layer B have good agreement, so the above judgment matrix A and B_i can be used to build sprinting ability evaluation model.

Using the eigenvectors and eigenvalues of judgment matrix obtained above, we can obtain the local weights of 24 third layer indicators. Then conduct quadrature with local weights of higher level indicators, global weight can be obtained shown in TABLE 4 below:

TABLE 4 : Sprint Comprehensive quality evaluation index weight table

First layer index	Secondary index	Weight	Third layer index	local weight	Comprehensive weight
A	B1	0.37	C1	0.06	0.022
			C2	0.21	0.078
			C3	0.16	0.059
			C4	0.19	0.070
			C5	0.15	0.056
			C6	0.23	0.085
	B2	0.20	C7	0.18	0.036
			C8	0.24	0.048
			C9	0.58	0.116
	B3	0.35	C10	0.33	0.116
			C11	0.24	0.084
			C12	0.28	0.098
			C13	0.15	0.053
	B4	0.08	C14	0.42	0.034
			C15	0.08	0.006
			C16	0.26	0.021
			C17	0.24	0.019

Combining with the above constructed evaluation index system, the judgment matrix proven to meet the consistency condition, as well as the local and comprehensive weight of each indicator, you can calculate the overall quality index of each long jumper to achieve effect that quantify the long jump sports effect, and then conduct the evaluation and analysis for a number of players. Where each player's comprehensive quality index is calculated as follows:

$$A_I = \sum_{i=1}^{n} d_i w_i \tag{7}$$

In Formula, A_I represents the overall quality index of the player, $d_i\,(0 \le d_i \le 1)$ means the evaluation result of the i–th indicator,

First define the mean value and standard deviation of the j-th indicator for the f-th sample:

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

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

Then the raw data is normalized to:

$$x_{ij}' = \left(x_{ij} - x_j\right)/s_j \tag{10}$$

Then use extreme standardization formula to map standardized data into $[0,1]$, namely:

$$x_{ij} = \frac{x_{ij}' - x_{j\min}'}{x_{j\max}' - x_{j\min}'} \tag{11}$$

Where: $x_{j\min}'$ and $x_{j\max}'$, respectively, mean the minimum and maximum values of $x_{1j}', x_{2j}', \ldots, x_{fj}'$; x_{ij} is the standardized results of the j–th index value for the i-th sample.

The empirical study selected 40 sophomore boys in our school, including 20 students of sports majors, 20 non-sports majors, aged between 19-21 years old; the results are the best annual 100m sprint results; the various indicators data are from the annual evaluation; and the indicator values is standardized. Based on the above sprint ability formula and each index weight we have

$$A_I = \sum_{i=1}^{17} d_i w_i = 0.022d_1 + 0.078d_2 + 0.022d_3 + \cdots + 0.019d_{17},$$

use the data in TABLE 5 to calculate the sprinting ability evaluation results for each sample, as shown in TABLE 5:

TABLE 5 : The comparison of the model evaluation results with the annual best performance

No.	1	2	3	4	5	6	7	8	9	10
Evaluation value	0.728	0.750	0.686	0.728	0.637	0.646	0.631	0.608	0.622	0.616
Measured value(s)	11.58	11.20	11.72	11.65	12.03	12.64	12.79	13.23	13.02	12.41

CONCLUSIONS

Comparing the sprinting ability evaluation results in this model with the measured annual 100m best results, we can find that the sprinting ability evaluation system can well reflect the level of athletic ability; the results are objective and accurate. The quantified results can effectively avoid the volatility of performance due to play stability and motion state. By the horizontal comparison of sports major students and non-sports major students, the model can effectively identify and quantify the effects of physical condition and the improvement of special quality after long-term training, which has broad applicability. These results provide a high reference value for the future athlete selection, training, and performance improvement.

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