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The long jump comprehensive strength influential factor analysis based on PCA

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ABSTRACT

This paper aims at the problems that long jump performance is more volatile and it is difficult to quantify the overall strength of athletes, uses mathematical tools to establish a scientific and reasonable long jump comprehensive strength evaluation index system. It uses the Principal Component Analysis (PCA) method to find the main factors, analyzes the results combining with expert advice, jointly determines the AHP weight of each index, thereby establishes the long jump comprehensive strength evaluation system model; through empirical testing, the results are scientific and rational, and can effectively solve the overall strength quantization problem of long jump athlete's.

KEYWORDS

Principal component analysis;
Hierarchical analysis;
Long jump;
Factor analysis.

INTRODUCTION

How to improve the level of long jump is the issue that track and field has studied for many years. Various statistical methods and artificial intelligence models are constantly being used to study the problem of long jump; research methods are more diverse and scientific, also have made a lot of progress. Such as Yu Jun and others used multiple regression method to conduct difference analysis for the parameters mean, compare the technical parameters of domestic and international elite athletes to identify the factors causing differences in the performance; Zhao Bing-jun used cluster analysis method to study the evaluation index system that may affect the long jump performance; Wang Ying and others also conducted analysis on the factors that affect the long jump performance in many ways.

This paper, through a large number of relevant information and the latest research advances in the field at home and abroad, aims at the problems that long jump performance is more volatile and it is difficult to quantify the overall strength of athletes, first establishes a scientific and reasonable evaluation index system; then combing the Principal Component Analysis with analytic hierarchy process, it uses Principal Component Analysis to help determine the index weights in hierarchical analysis model, and overcomes the shortcomings of strong subjectivity in traditional expert scoring method; it conducts research and empirical analysis combining with physical fitness and special technical data of many outstanding athletes, and obtains more reasonable and accurate evaluation model of long jumping performance influencing factors; it has a very positive meaning to provide scientific and quantitative basis for the improvement of

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training methods and long jumpers' selection.

ESTABLISHMENT OF EVALUATION INDEX SYSTEM

The indicator selection method used in this paper is the literature and expert questionnaire method; it uses the study results of Zhao Bing-jun et al for reference, takes into account from objective factors, basic athletic ability factors, specific technical factors, psychological factors, mental factors and other factors, improves the previous established index system to conduct trade-offs of various indicators, and ultimately determines the evaluation index system of this article. It includes both qualitative and quantitative indicators index, a total of 5 first layer indicators and 24 secondary layer indicators, as shown in TABLE 1:

TABLE 1 : Influencing factor evaluation indexes of long jump performance

Index system	First layer index	Secondary layer index
Influencing factor index system of long jump athletic ability A	Objective Factor B1	Age C1
		Height (cm) C2
		Weight (kg) C3
		Quetelet index (weight/height ×1000) (g/cm)C4
		Lower limbs length/height × 00% C5
		Heart rate (time/m) C6
	Basic athletic ability B2	30m run(s) C7
		Rear throw shot C8
		Standing trip jump(m) C9
		Run-up reach(m) C10
		100m run(m) C11
	Specific technique factor B3	Run-up technique C12
		Run-up and take-off combined technique C13
		Take-off technique C14
		Soar technique C15
		Touchdown technique C16
		Pedal accuracy C17
	Psychological factors B4	Reaction speed C18
		Psychology stability C19
		Tenacious fighting C20
		Major interest C21
	Intelligence factor B5	Receptivity ability C22
		Strain ability C23
		Thinking ability C24

INFLUENCING FACTORS OF LONG JUMP ATHLETIC ABILITY

Firstly we use the statistical function in spss17.0 software, conduct Principal Component Analysis on the six secondary layer indicators of the first layer indicator objective factors, and obtain that the cumulative contribution rate of three factors is more than 80%. These three main factors are denoted as F_1, F_2, F_3, carry through orthogonal rotation on it, and obtain the maximum variance load matrix as shown in TABLE 2.

And then the Principal Component Analysis results of six secondary layer indicators under first layer indicator of objective factor:

$$X_1 = 0.434F_1 - 0.542F_2 + 0.156F_3$$
$$X_2 = 0.708F_1 - 0.460F_2 + 0.106F_3$$
$$X_3 = 0.161F_1 - 0.123F_2 + 0.883F_3$$
$$X_4 = -0.532F_1 + 0.614F_2 + 0.009F_3$$
$$X_5 = 0.643F_1 + 0.373F_2 + 0.256F_3$$
$$X_6 = 0.077F_1 + 0.031F_2 + 0.447F_3$$

TABLE 2 : Orthogonal rotation loading matrix of objective factors

Secondary layer index	Principal factor		
	F_1	F_2	F_3
Age C1	0.434	-0.542	0.156
Height C2	0.708	-0.460	0.106
Weight C3	-0.161	0.123	-0.883
Quetelet index (weight/height×1000) C4	-0.532	0.614	-0.009
Lower limbs length/ height×100% C5	0.643	0.373	-0.256
Heart rate (time/m) C6	-0.077	0.031	0.447

As can be seen from the above results, height and leg length / height are the most important factors; primary factor F_2 is mainly determined by two indicators: the age status and Quetelet index; primary factor F_3 is mainly affected by body weight and heart rate. Conduct regression analysis of each factor, and then calculate the weighted sum by the variance contribution rate of each factor, and obtain the composite score of each factor:

$$F_1 = 0.37X_1 + 0.723X_2 - 0.115X_3 - 0.509X_4 + 0.588X_5 - 0.188X_6$$
$$F_2 = -0.654X_1 - 0.132X_2 + 0.184X_3 + 0.588X_4 + 0.166X_5 + 0.36X_6$$
$$F_3 = 0.29X_1 + 0.039X_2 - 0.694X_3 - 0.33X_4 + 0.245X_5 + 0.417X_6$$

Finally, composite score function of first layer index objective factor is:

$$A_1 = 31648F_1 + 25872F_2 + 20402F_3 \quad (1)$$

Similarly, one can get the composite score of other five indicators and conduct Principal Component Analysis on all six indicators combining score. Thus you can get the relative importance of each indicator as well as the influence degree on the long jump performance, providing some basis for the weights determination when further establish AHP model.

EVALUATION MODELING AND APPLICATION OF LONG JUMP ATHLETIC ABILITY

This paper uses the Principal Component Analysis and expert scoring method to construct judgment matrix, asks 10experts in related fields to do pair-wise comparison on the relative importance of index system elements in accordance with 1~9 scale method, combining the expert survey results with the above Principal Component Analysis results, and finally gets the importance judgment matrix for each layer indicators corresponding to the superior layer indicators, shown as follows:

$$A=\begin{pmatrix}1 & 1/3 & 1/2 & 3 & 4\\ 3 & 1 & 2 & 3 & 4\\ 2 & 1/2 & 1 & 2 & 3\\ 1/3 & 1/3 & 1/2 & 1 & 2\\ 1/4 & 1/4 & 1/3 & 1/2 & 1\end{pmatrix} \quad B_1=\begin{pmatrix}1 & 1/4 & 2 & 1 & 1/3 & 1\\ 4 & 1 & 4 & 3 & 2 & 3\\ 1/2 & 1/4 & 1 & 1/2 & 1/3 & 1/2\\ 1 & 1/3 & 2 & 1 & 1/2 & 1\\ 3 & 1/2 & 3 & 2 & 1 & 3\\ 1 & 1/3 & 2 & 1 & 1/3 & 1\end{pmatrix}$$

$$B_2=\begin{pmatrix}1 & 3 & 2 & 1/2 & 4\\ 1/3 & 1 & 1/2 & 1/3 & 2\\ 1/2 & 2 & 1 & 1/2 & 2\\ 2 & 3 & 2 & 1 & 3\\ 1/4 & 1/2 & 1/2 & 1/3 & 1\end{pmatrix} \quad B_3=\begin{pmatrix}1 & 1/2 & 1 & 1 & 3 & 1/3\\ 2 & 1 & 3 & 2 & 4 & 1/2\\ 1 & 1/3 & 1 & 1/2 & 2 & 1/3\\ 1 & 1/2 & 2 & 1 & 3 & 1/2\\ 1/3 & 1/4 & 1/2 & 1/3 & 1 & 1/4\\ 3 & 2 & 3 & 2 & 4 & 1\end{pmatrix}$$

$$B_4=\begin{pmatrix}1 & 1/4 & 1/3 & 1/3\\ 4 & 1 & 2 & 2\\ 3 & 1/2 & 1 & 2\\ 3 & 1/2 & 1/2 & 1\end{pmatrix} \quad B_5=\begin{pmatrix}1 & 1/2 & 4\\ 2 & 1 & 7\\ 1/4 & 1/7 & 1\end{pmatrix}$$

The first layer index weight vector is $W = (0.20, 0.33, 0.25, 0.14, 0.08)^T$, and the secondary index weight vector is:

$W_1 = (0.13, 0.26, 0.10, 0.15, 0.22, 0.14)^T$

$W_2 = (0.24, 0.15, 0.20, 0.29, 0.12)^T$

$W_3 = (0.16, 0.20, 0.14, 0.18, 0.08, 0.24)^T$

$W_4 = (0.18, 0.30, 0.27, 0.25)^T$

$W_5 = (0.35, 0.46, 0.19)^T$.

Then conduct consistency test for each judgment matrix (take the judgment matrix A for example), first calculate the maximum eigenvalue λ_{max}:

$$AW=\begin{pmatrix}1 & 1/3 & 1/2 & 3 & 4\\ 3 & 1 & 2 & 3 & 4\\ 2 & 1/2 & 1 & 2 & 3\\ 1/3 & 1/3 & 1/2 & 1 & 2\\ 1/4 & 1/4 & 1/3 & 1/2 & 1\end{pmatrix} \cdot \begin{pmatrix}0.20\\ 0.33\\ 0.25\\ 0.14\\ 0.08\end{pmatrix} = \begin{pmatrix}1.175\\ 2.17\\ 1.335\\ 0.602\\ 0.366\end{pmatrix}$$

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(AW)_i}{w_i} = \frac{1}{5}\left(\frac{1.175}{0.20}+\frac{2.17}{0.33}+\frac{1.335}{0.25}+\frac{0.602}{0.14}+\frac{0.366}{0.08}\right) = 5.33$$

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{5.33-5}{4} = 0.0825$$

$$CR = \frac{CI}{RI} = \frac{0.0825}{1.12} = 0.074$$

$CR = 0.074 < 0.1$, 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 long jump comprehensive quality 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 3 below:

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:

$$A_I = \sum_{i=1}^{19} d_i w_i \quad (2)$$

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In Formula (2), A_I represents the overall quality index of the player, d_i means the evaluation result of the i–th indicator, which is a standardized data ($0 \le d_i \le 1$); for the values of each indicator, that can be quantified will directly conduct standardization and remove the effect of dimension; That cannot be quantified will be determined using score averaging method by a number of experts.

TABLE 3 : Comprehensive quality evaluation index weight table

First layer index	Secondary index	Weight	Third layer index	local weight	Comprehensive weight
A	B1	0.20	C1	0.13	0.026
			C2	0.26	0.052
			C3	0.10	0.020
			C4	0.15	0.030
			C5	0.22	0.044
			C6	0.14	0.028
	B2	0.33	C7	0.24	0.079
			C8	0.15	0.050
			C9	0.20	0.066
			C10	0.29	0.096
			C11	0.12	0.040
	B3	0.25	C12	0.16	0.040
			C13	0.20	0.050
			C14	0.14	0.035
			C15	0.18	0.045
			C16	0.08	0.020
			C17	0.24	0.060
	B4	0.14	C18	0.18	0.025
			C19	0.30	0.042
			C20	0.27	0.038
			C21	0.25	0.035
	B5	0.08	C22	0.35	0.028
			C23	0.46	0.037
			C24	0.19	0.015

In order to verify the effectiveness of the model, this paper selects the indicator data of six track and field team long jumpers, which is used to empirical research on the evaluation model. The indicators data is from the Sports Council website, the results after numerical standardization of each indicator are shown in TABLE 4:

TABLE 4 : The standardized results of each index score

Index	1	2	3	4	5	6
C1	0.85	0.82	0.70	0.87	0.68	0.69
C2	0.72	0.78	0.76	0.88	0.52	0.50
C3	0.69	0.66	0.64	0.69	0.61	0.60
C4	0.63	0.57	0.40	0.75	0.44	0.49
C5	0.68	0.52	0.46	0.84	0.49	0.41
C6	0.70	0.75	0.65	0.62	0.55	0.69
C7	0.50	0.59	0.57	0.73	0.60	0.56
C8	0.77	0.84	0.80	0.69	0.60	0.70
C9	0.61	0.63	0.61	0.58	0.60	0.66
C10	0.81	0.87	0.72	0.80	0.66	0.65
C11	0.75	0.85	0.81	0.85	0.74	0.73
C12	0.80	0.89	0.74	0.87	0.83	0.79
C13	0.87	0.80	0.70	0.86	0.80	0.70
C14	0.75	0.80	0.70	0.67	0.64	0.71
C15	0.70	0.72	0.69	0.69	0.65	0.68
C16	0.69	0.71	0.65	0.74	0.62	0.64
C17	0.65	0.69	0.68	0.70	0.70	0.64
C18	0.71	0.74	0.70	0.78	0.72	0.70
C19	0.64	0.67	0.62	0.70	0.57	0.59
C20	0.78	0.58	0.77	0.71	0.75	0.78
C21	0.85	0.63	0.74	0.68	0.84	0.84
C22	0.91	0.74	0.70	0.92	0.68	0.86
C23	0.82	0.86	0.64	0.90	0.63	0.67
C24	0.73	0.80	0.66	0.85	0.71	0.74
Year Best result (M)	6.91	6.93	6.86	7.02	6.80	6.85

Based on the above long jump overall strength calculation formula and the weight of each index we have:

$$A_I = \sum_{i=1}^{19} d_i w_i = 0.026d_1 + 0.052d_2$$

$$+ 0.020d_3 + \cdots + 0.015d_{24} \qquad \textbf{(3)}$$

Substitute d_i of TABLE 6 into the above equation (3) we can obtain that long jump overall strength scores of these six athletes are respectively 0.724, 0.730, 0.673, 0.760, 0.648 and 0.656. In contrast with the actual results, the evaluation results are accurate and objective, the score situation is basically consistent with their actual performance distribution. The above empirical analysis shows that the model established in this paper is safe and effective. As can be seen from the analysis results the basic athletic ability and special technical capabilities are the prerequisites that affect the overall strength of long jumpers; height, body shape, leg length, psychological quality and other factors also are an important part of the long jump overall strength.

CONCLUSIONS

On the basis of establishing a scientific and rational long jump comprehensive strength evaluation index, this paper uses the Principal Component Analysis to identify the main factors, and as a basis establishes long jump comprehensive strength evaluation system combining with AHP; through empirical testing, it can objectively and accurately assess the overall strength of the long jump athletes, and has a high application value for the formulation of targeted training programs, the improvement of the long jump and scientific athletes selection.

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