Construction of a neural network model for performance prediction in shot put athletes

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Abstract: This paper is to investigate the role of artificial neural network models in the prediction of sports performance and to establish artificial neural network models to evaluate the correlation between athletes' special performance and special physical quality. The results show that the artificial neural network model overcomes the shortcomings of multiple regression models and gray models that require a pre-determined mathematical model, and more accurately reflects the functional relationship between the training indexes of the special quality of shot put athletes and the special athletic performance, and more accurately predicts the special performance of shot put athletes. It further showed that the special physical quality of shot put athletes is an important basis for their special athletic ability. With the physical quality index as the independent variable and the special performance as the dependent variable, the prediction model of the athletes' special performance can be established, which can accurately diagnose and evaluate the development level of the athletes' physical quality, and clarify the key points and objectives of the training content, so as to improve the scientific level of the training of shot put.

1. Introduction

Athletic performance refers to the athlete's ability to perform in sports, the basis of which is specific physical qualities, which largely determine the athlete's ability to perform specific sports[1, 2]. In general, the relationship between athletic performance and its impact indicators is complex and nonlinear. At present, the evaluation of shot put athletic performance is still qualitative, and there is not yet a systematic, quantitative evaluation method. Neural network, as an important discipline of modern nonlinear science, have developed rapidly in recent years and has been widely used in the field of sports. Unlike traditional nonlinear recognition methods, neural network recognition is not limited by the nonlinear model. Neural network recognition is based on the input/output data pairs of the system to be recognized, and a nonlinear mapping describing the input/output relationship of the system is obtained by learning. Given an input, it can obtain an output without knowing the mathematical relationship between the input and the output. This self-learning feature makes neural networks unique in solving complex nonlinear problems. This paper is to investigate the role of artificial neural network models in the prediction of sports performance and to establish artificial neural network models to evaluate the correlation between athletes' special performance and special physical quality.
2. Neural Network Model Construction

2.1. Research object
Taking the special performance and quality training level from 2015 to 2018 as the historical sample, this paper analyzes the correlation between the athletes' special performance and quality training index. It establishes the prediction model of the athletes' special performance. Based on this prediction model, the special performance in 2019 and 2020 was forecasted. The artificial neural network has two kinds of network topology, which is, feed-forward network and feedback network. The feed-forward network is mainly function mapping, which is used for pattern recognition and function approximation. It has been proved that the multi-layer feed-forward network can approximate any continuous function, that is to say, the multi-layer feed-forward network can be used to establish the prediction model of athletes' special performance, which can fit any functional relationship between the special performance and quality training index, and genuinely reflect their intrinsic characteristics, to overcome the multiple regression model. Deficiency of type and grey model.

Table.1 Quality training level and special achievement

| Years     | Historical | prediction |
|-----------|------------|------------|
| 2015      | 4 kg in situ(m) | 18.60      |
| 2016      | 2.31       | 18.80      |
| 2017      | 2.35       | 19.10      |
| 2018      | 2.47       | 19.40      |
| 2019      | 2.50       | 20.00      |
| 2020      | 2.77       | 20.40      |
| Standing long jump(m) | 2.31 | 2.35 | 2.47 | 2.50 | 2.77 | 2.77 |
| High turnover(kg) | 57 | 60 | 77 | 90 | 95 | 100 |
| Snatch (kg) | 45 | 50 | 55 | 60 | 70 | 75 |
| Horizontal push(kg) | 52 | 60 | 80 | 85 | 90 | 100 |
| Slipping(m) | 15.70 | 16.80 | 18.30 | 19.10 | 19.80 | 20.90 |
| Standing Three Jump(m) | 7.40 | 7.30 | 7.50 | 7.85 | 8.1 | 8.20 |
| Full squat(kg) | 80 | 100 | 130 | 140 | 145 | 155 |
| Run(m/s) | 4.26 | 4.18 | 3.95 | 3.93 | 3.85 | 3.83 |

2.2. Neuron characteristics
The primary processing unit of the connection mechanism and the neurophysiological analogy are often called neurons. Each neuron model that constructs the network simulates a biological neuron, as shown in Figure 2. The neuron unit consists of multiple inputs, \( i = 1, 2, \ldots, n \) is composed of an output \( y \). The intermediate state is represented by the weight and input of the input signal, and the output as a fellow.

\[
\text{net}_{k} = \sum_{i} w_{i,k} Q_{k} + \theta_{k} \quad (1)
\]

In Formula (1), \( \theta_{k} \) is the bias of the neuron unit, \( w_{ij} \) is the connection weight coefficient (for the excited state, \( w_{ij} \) is positive, for the suppressed state, \( w_{ij} \) is negative), \( n \) is the number of input signals, \( y_{j} \) is the output of the neuron, \( t \) is the time, \( f(\cdot) \) is the output transform function, sometimes called the excitation or excitation function. These three functions are continuous and nonlinear. The valued function can be expressed as follows[3, 4].

\[
f(x) = \begin{cases} 
1, & x > 0 \\
0, & x < 0 
\end{cases} \quad (2)
\]

As shown in Figure 1 (a). The conventional S shape function is shown in Figure 1(b).

\[
f(x) = \frac{1}{1 + e^{-ax}}, 0 < f(x) < 1 \quad (3)
\]
The hyperbolic tangent function is often used to replace the conventional S-shaped function because the output of the S-shaped function is positive, and the output value of the hyperbolic tangent function can be positive or negative. The hyperbolic tangent function is shown as following:

$$f(x) = \frac{1 + e^{-ax}}{1 + e^{ax}}, \quad -1 < f(x) < 1$$  (4)

The result is shown in Figure 1.

![Figure 1: The transformation functions in neurons](image)

After the structure of the feed-forward neural network is determined, it is necessary to study the neural network. In the learning algorithm of the feed-forward neural network, the most basic and vital learning algorithm is the error backpropagation algorithm. Its presentation marks a breakthrough in the theoretical research of artificial neural networks. BP learning algorithm is composed of forwarding propagation and backpropagation. In the forward propagation process, the input signal travels from the input layer to the hidden layer and the output layer by layer through the action function. The state of each layer of neurons only affects the state of the next layer of neurons. If the desired output is not obtained in the output layer, the error signal is transferred back to the original connection path. By modifying the connection weights of neurons in each layer, the output error signal is minimized. This learning process is repeated until the output error signal is less than a given value, so a set of connection weights mapping the input and output signals are obtained, and the trained neural network is obtained[5].

3. Neural Network Prediction Model for Special Performance

The basic idea of the prediction model for the performance of throwing events proposed in this paper is to construct the evaluation system of throwers' movement and technical level. Then, the values are screened out by correlation analysis and cluster analysis. Finally, a prediction model of throwing athletes' special performance is established by using the neural network [3, 6].

3.1. Determination of quality training indicators

Based on the historical data from 2015 to 2018, the correlation analysis and correlation analysis between the 12 quality training indexes and the special performance of the athletes in Table 1 are carried out. The correlation coefficient and correlation degree are shown as Table 2, where we can see that the correlation coefficient and degree between the 12 quality training indexes and the athletes' special achievements are high. Moreover, according to the experts' long-term training experience of shot putters, it is confirmed that these 12 quality training indexes are closely related to the athletes' special performance.

| Years                        | Correlation coefficient | Correlation degree |
|------------------------------|-------------------------|--------------------|
| 4 kg before throwing (kg)    | 0.9200                  | 0.8521             |
| 4 kg after throwing (kg)     | 0.9029                  | 0.8595             |
| Activity                          | Correlation coefficient | Improvement |
|----------------------------------|-------------------------|-------------|
| 4 kg in situ(m)                  | 0.9880                  | 0.9702      |
| Standing long jump(m)            | 0.8863                  | 0.9096      |
| High turnover(m)                 | 0.9377                  | 0.8711      |
| Snatch(m)                        | 0.9704                  | 0.9125      |
| Horizontal push(kg)              | 0.9732                  | 0.8206      |
| Slipping(m)                      | 0.9650                  | 0.7633      |
| Standing Three Jump(m)           | 0.9954                  | 0.8695      |
| Full squat(m)                    | 0.9356                  | 0.8300      |
| Run(m)                           | -0.8963                 | 0.8805      |

3.2. Determination of neural network structure

In order to establish a neural network model between the physical training indicators and the special performance, the structure of the neural network must be determined first. The number of input neurons in the neural network is 12, corresponding to 12 physical training indices, and the number of output neurons is 1, which represents special performance. The number of hidden layers of the neural network is one layer, and the number of hidden neurons is 20. The transfer function of each neuron is a linear function.

It is taking the historical data of athletes' quality training and special achievements from 2015 to 2018 as training samples of the neural network. BP learning algorithms are used to learn training samples. After learning, the neural network can reflect the functional relationship between the quality training indicators and special performance. That is, it can get the prediction model of the athletes' special performance.

3.3. Program design

The learning process of the neural network is essentially a process of optimizing the weights of the neural network. This learning process needs hundreds of iterations, each of which includes calculating all the output results of neurons and correcting the value of connections. Therefore, the amount of computation in the learning process of the neural networks is enormous, which can not be accomplished by calculators alone, but by using the current software development tools and writing specific programs. Here, we use the neural network development tool in MATLAB 5.3 software to realize the development of the neural network prediction model of shot putters, which is very convenient and easy. The MATLAB program of it is as follows:

```matlab
p = [11.50 11.70 14.10 15.40 11.33 14.05 16.60 17.80 11.60 12.80 14.10 15.40 2.33 2.35 2.74 2.77 50 60 80 90 45 50 55 60 50 60 80 95 15.70 16.80 18.30 19.10 7.10 7.30 7.50 7.85 80 100 130 140, 26.4, 18.3, 95.3, 93.14, 17.13, 77.12, 91.12, 70]'; % Input data of training samples.
t = [13.30 14.91 15.77 17.88]; % Output data of training samples
[pn, minp, maxp, tn, mint, maxt] = premnmx(p, t); % Normalization of training samples
net = newff(minmax(pn), [20], {purelin, purelin}, trainoss); % Building neural network structure
net.trainParam.show = 5; net.trainParam.epochs = 300; net.trainParam.goal = 1e-4; % Setting training parameters
net = train(net, pn, tn); % Training neural network
```

The learning process of the whole neural network takes 2.1 hour (the CPU of the computer is 3400MHz, and the memory is 8G).

3.4. Fitting accuracy and prediction accuracy of prediction models

This paper put the athletes' quality training index data from 2015 to 2016 into the prediction model of the neural network; The special performance of athletes can be calculated. The results are shown in
Table 3. By using the multiple linear regression models and the least square method, the linear relationship between the quality training index and the special achievement from 2017 to 2018 is fitted. The obtained mathematical model is as follows.

\[
y = 17.56 = 0.08x_1 - 0.28x_2 + 9.85x_3 - 3.58x_4 - 0.02x_5 - 0.05x_6 + 0.03x_7 + 0.20x_8 + 3.28x_9 - 0.02x_{10} - 0.94x_{11} - 1.49x_{12}
\]  

(5)

In this paper, the special results of 2015-2018 are calculated by this mathematical Formula. The results are shown in Table 3, where we can be seen that the error between the calculated value and the actual value of the special results is much smaller by using the neural network prediction model than by using the multiple linear regression models, which shows that the neural network model can better fit the quality. The fitting accuracy of the functional relationship between training level and special performance is high.

| Actual value / m | Neural network model | Multiple regression model |
|------------------|----------------------|--------------------------|
|                  | Prediction error / m| Prediction error / m     |
| 2015 13.30       | 13.263               | 0.037                    |
| 2016 14.91       | 14.913               | -0.003                   |
| 2017 15.77       | 15.751               | 0.019                    |
| 2018 17.88       | 17.885               | -0.005                   |

By inputting the data of athletes' quality training in 2019 and 2020 into the neural network model, the predicted value of athletes' special achievements in 2019 and 2020 are obtained. The results are shown in Table 4. Multiple linear regression models were also used to predict athletes' special performance. Compare the prediction accuracy of the two prediction models. It can be seen from Table 4 that the prediction accuracy of the neural network model is higher than that of the multiple linear regression models.

| Actual value / m | Neural network model | Multiple regression model |
|------------------|----------------------|--------------------------|
|                  | Prediction error / m| Prediction error / m     |
| 2019 18.56       | 18.538               | 0.022                    |
| 2020 18.70       | 18.790               | 0.090                    |

It can be seen from the above calculation results that the neural network model can better reflect the functional relationship between the athletes' quality training level and the special performance, thus establishing a better prediction model for athletes' special performance.

4. Conclusion

There is a certain functional mapping between athletes' special performance and the level of specialized physical training. The theoretical model of the relationship between athletes' special performance and special physical training can be used to accurately predict athletes' special performance. It provides a scientific theoretical basis for the development of special physical training. In this paper, a neural network-based model for predicting athletes' special performance is proposed. The model overcomes the shortcomings of multiple regression models and gray models, and does not require prior determination of the mathematical expressions of the athlete-specific performance prediction model, reflecting more objectively the relationship between the level of athlete-specific physical training and the specific performance. The relationship between them is higher and the prediction accuracy is also higher. Through the neural network special performance prediction model, coaches and athletes can more accurately arrange a more scientific training plan. However, it is essentially a local optimization
method, which is prone to fall into local minima, and there is a contradiction between learning speed and accuracy, which should be considered for further improvement.

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