Neural network analysis of muscle strength characteristics of men's volleyball players

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Abstract. In this paper, the muscle strength of knee and ankle joints of Chinese men's volleyball players was tested and analyzed at constant speed to reveal their strength characteristics and provide experimental support for related research. Through the established neural network model, it can be known that the RBF network model can predict the variation of human muscle strength with the relative peak torque of joint flexor muscle group. The analysis of neural network shows that men's volleyball competition requires very high relative peak torque of the knee and ankle muscle groups. In addition, the relative peak torque of the knee and ankle muscle groups of a few athletes is small, so they should be subjected to targeted strength training. By comparing the RBF network model with BP network and Elman network model, it is shown that the RBF network model has higher accuracy and stronger generalization ability.

Keywords: Knee joint, Muscle group, Torque, Neural network.

1 Introduction

Volleyball is a net-separated competitive sport. Although there is no direct physical collision between athletes and opponents in the game, the technical characteristics of volleyball determine that athletes need to frequently perform repetitive actions such as jumping, squatting, falling and hitting the ball. These actions make the knees, ankles, waist, shoulders and other parts of athletes bear great loads[1] .

2 Experimental measurement

This study was conducted at the Sports Science Research Institute of the General Administration of Sport of China, using the German ISOMED2000 isokinetic strength testing system to measure the concentric strength of the knee and ankle muscle groups in 19 elite male volleyball players[2]. During the test, an angular velocity of 60/s (slow) was selected for strength testing, while an angular velocity of 240/s (fast) was used for power testing. The specific testing procedures are as follows: Basic information collection of athletes: comprehensively obtain the basic status data of athletes, including height, weight,

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training years, injury history and other information, to provide basic data for subsequent data analysis[3].

Data collection and recording: After the test is completed, the data will be saved to the specified storage device immediately[4], and the test values of each athlete will be accurately recorded to ensure the integrity and accuracy of the data. Test wrap-up: remove the fixation device for the athlete and print the test report. See Table 1 below for detailed test parameters.

Table 1. Muscle groups testing and test parameters.

Test location	test muscle group	test speed	test pattern	sports scope	tes t side	repeat number of times	number of test groups	rest time
knee joint	flexion\ extension	60°/s	centripetal contraction	10° ~90°	Left\ right	4	1	60s
ankle joint	Dorsal metatarsa lflexion	60°/s	centripetal contraction	-30° ~25°	Left\ right	4	1	60s

2.1 Knee strength test results for men's volleyball players

Table 2. Relative torque of knee muscles in men's volleyball athletes.

test speed	test joint	Relative peak moment of flexor muscle groups (Nm/kg)			Relative peak moment of extensor muscle groups (Nm/kg)		
		$\bar{X} \pm SD$	minimum value	maximum value	$\bar{X} \pm SD$	minimum value	maximum value
60°/s (n=19)	Left knee	$1.81 \pm 0.20^{*\#}$	1.43	2.18	3.01±0.54	2.12	4.12
	right knee	$1.85 \pm 0.22^{*\#\#}$	1.35	2.19	3.12±0.66	1.85	4.10
240°/s (n=19)	Left knee	$1.55 \pm 0.30^{**\#}$	0.83	2.02	2.11±0.41	1.45	2.84
	right knee	$1.53 \pm 0.22^{**\#\#}$	1.08	1.99	2.18±0.37	1.62	2.94

2.2 The ankle strength test results of Chinese men's volleyball players

Table 3. Relative Torque of Ankle Muscles in Men's Volleyball Athletes (n=19 person).

test speed	test joint	Relative peak moment of flexor dorsi (Nm/kg)			Relative peak moment of flexor plantaris (Nm/kg)		
		$\bar{X} \pm SD$	minimum value	maximum value	$\bar{X} \pm SD$	minimum value	maximum value
60°/s (n=19)	left ankle	0.43±0.06※ab	0.32	0.53	1.28±0.34	0.59	1.8
	Right ankle	0.46±0.08※aab	0.36	0.65	1.32±0.33	0.6	1.82
240°/s (n=19)	left ankle	0.26±0.05※※a	0.16	0.34	0.72±0.23	0.33	1.23
	Right ankle	0.31±0.06※※aa	0.19	0.42	0.72±0.23	0.3	1.25

3 Building neural networks for predicting muscle strength in athletes

In the field of athlete muscle group strength analysis, artificial neural networks have been used to predict the correspondence between knee strength, ankle strength, and human motor strength analysis and physical exercise conditions. RBF neural network has the global approximation property and the best approximation performance, which avoids the tedious calculation of BP network, fast learning, no local optimal problem, and can better reflect the actual situation of the system[5]. Therefore, RBF (Radial Basis Function) neural network and BP (Back Propagation) neural network are used to predict the strength of muscle groups respectively. Through the comparison of two network prediction errors, this paper the superiority of RBF (Radial Basis Function) neural network over BP (Back Propagation) neural network is shown[6]. The structure of the network is shown in Figure Fig.1.

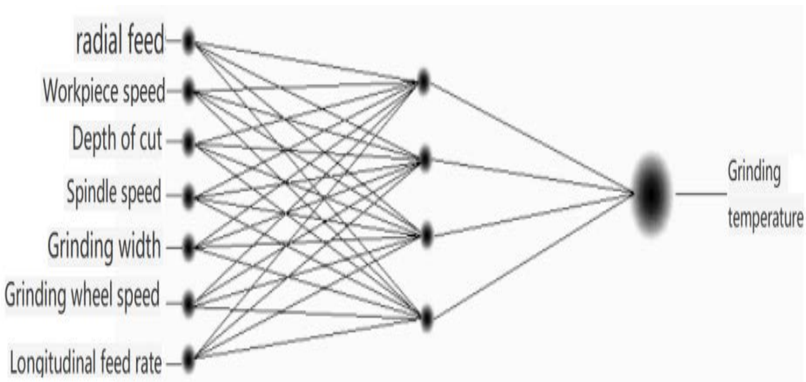

Fig.1. The network structure of grinding temperature forecast.

Based on the test data of knee joint and ankle muscle group strength on the body of volleyball players, the RBF neural network prediction model of human muscle group strength was developed. Where P is the training sample, T is the target sample, GOAL is the accuracy level, SPREAD is the width coefficient of the radial basis function, and MN is the maximum number of neurons. Finally, the analysis results of RBF network are compared with the traditional BP network model to illustrate the superiority of RBF network[9].

3.1 Sample data

The sample data used in this paper is derived from the test data of Chinese volleyball players.

3.2 Modeling of neural networks

During the testing of muscle strength in athletes, the main factors affecting muscle strength include the relative peak torque of the knee flexors (Nm/kg), the relative peak torque of the knee extensors (Nm/kg), the relative peak torque of the ankle dorsiflexors (Nm/kg), and the relative peak torque of the ankle plantarflexors (Nm/kg). The number of hidden layers is set to 15, and the target error for the network is set to 0.001. A total of 198 test samples are used for training, as shown in Table 3. Additionally[10], 12 forecast samples are used for testing to verify the network's generalization ability, as shown in Tab.4.

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Table 4. Test sample data.

M_{11}	M_{12}	M_{21}	M_{22}	M_{31}	M_{32}	M_{41}	M_{42}
1.81	1.85	3.01	1.85	0.32	0.36	0.59	0.60
1.79	2.01	3.58	4.10	0.53	0.65	1.80	1.82
1.83	1.83	2.46	2.00	0.36	0.38	0.65	0.63
1.81	1.68	2.09	3.62	0.40	0.40	0.71	0.68
1.79	1.98	4.01	2.36	0.45	0.45	0.73	0.73
1.81	1.91	2.67	2.34	0.50	0.53	0.90	0.76
1.82	1.82	2.89	2.76	0.38	0.56	0.96	1.05
1.82	1.86	2.61	3.15	0.48	0.58	1.05	1.18
1.83	1.83	2.98	3.56	0.32	0.61	1.12	1.26
1.79	2.02	2.46	3.38	0.53	0.36	1.19	1.32
1.80	1.86	2.09	3.67	0.36	0.38	1.26	1.46
1.81	1.91	4.01	2.85	0.40	0.40	1.28	1.58
1.82	1.98	4.02	4.08	0.45	0.45	1.32	1.63
1.81	1.91	2.38	2.16	0.50	0.48	1.47	1.68
1.79	1.82	2.67	2.71	0.52	0.53	1.58	1.76
1.80	1.86	2.89	3.38	0.46	0.56	1.63	1.81
1.82	1.83	2.39	3.96	0.51	0.61	1.71	1.82

3.2.1 Training of RBF Neural Networks

In the resume of RBF neural network model, the number of hidden layer neurons is an important factor affecting the prediction performance of the network. Since the default value of the hidden layer of the RBF network implemented by the Matlab toolbox is the number of sample trees, if the default value is taken, it may cause overfitting and affect the generalization ability.

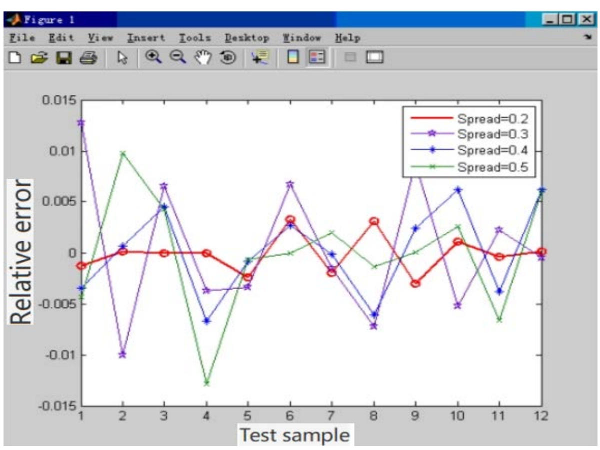

Fig.2. The prediction error of RBF network when spread take different values.

In this paper, the input samples for the RBF neural network used to predict grinding temperature consist of 8 parameters, with data that is quite dispersed and a large range of sample values. To accelerate the convergence speed of the network's learning and training process for modeling and prediction, 198 training samples were normalized, ensuring all training and prediction sample data fall within the [0,1] interval. The maximum number of hidden layer neurons was temporarily set at 150, with forecast errors for different spreads shown in Figure 2. The network training process is illustrated in Fig. 2.

$$x' = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{1}$$

From Fig. 3, it can be seen that the error of the time curve is within 0.5%, which is the smallest compared to other values, with minimal fluctuation in the error curve and a relatively smooth curve. From Fig 3, although the number of training times is the highest at 119 when , and other training times are smaller, when , the training times drop to 83, but the error has already exceeded 1%, and the training times are not much different from when . Therefore, we choose. At this point, the network's training times are 119. It can be known that the number of hidden layer neurons in the network model at this time is 119. Thus, the structure of the human muscle strength network model can be determined as: 7-119-11.

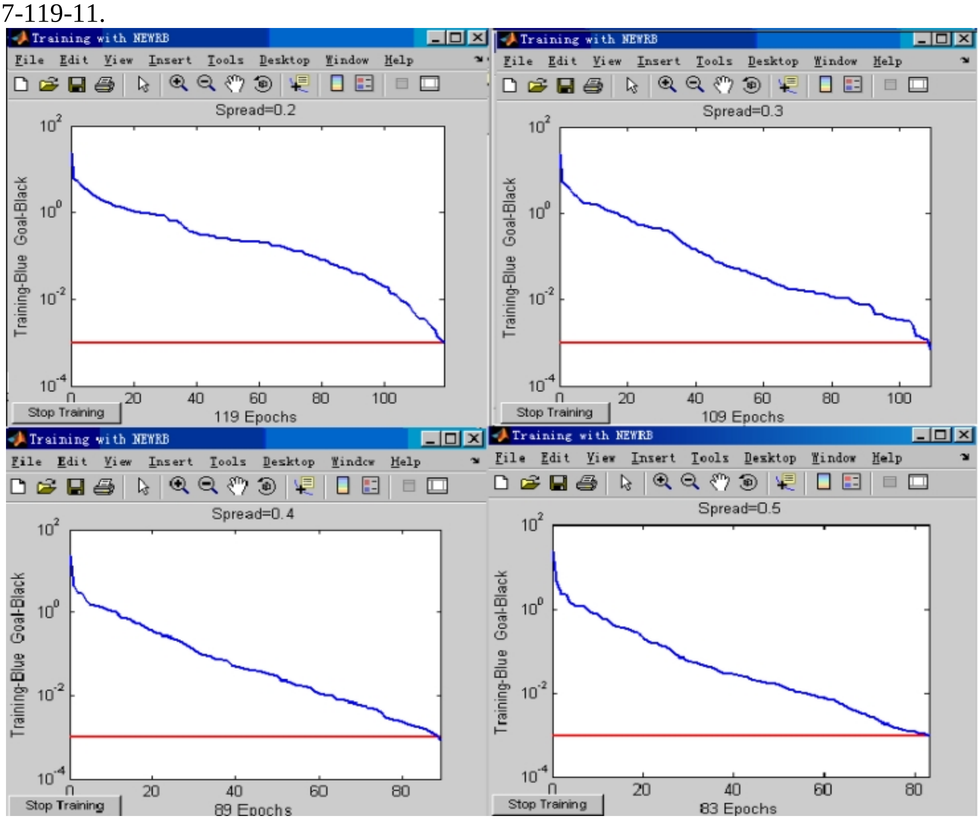

Fig.3. The training process of RBF network.

3.2.2 Training of BP Neural Networks

The basic idea of the BP algorithm is that for a losing sample, after the weight, threshold, and excitation function are calculated, an output is obtained, and then it is compared with the desired sample. When the training accuracy of the BP network reaches 0.001, the number of training times reaches 847 times, and the number of training times is higher than that of RBF, and its prediction error is also higher than that of RBF, close to 2%, and the error curve fluctuates violently, and the stability is poor.

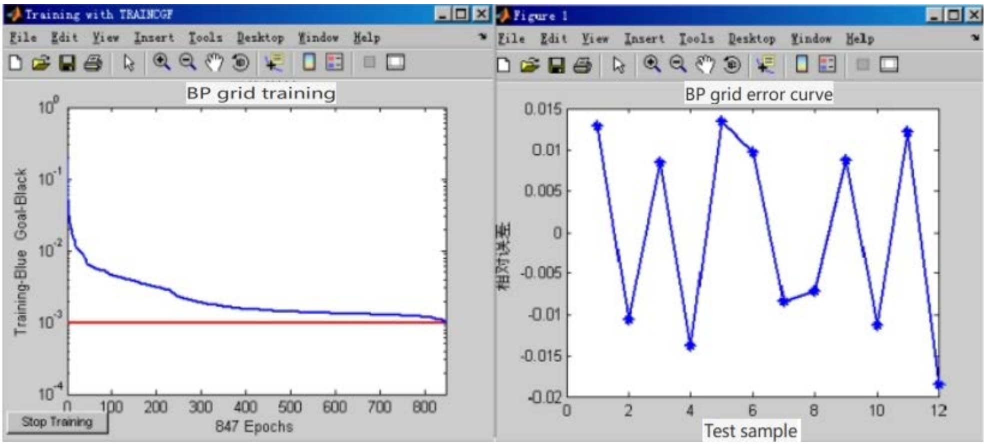

Fig.4. The training process and the error curve of BP network.

3.3 Analysis of the results of both models

Tab. 5 shows the comparison of the prediction results of the two networks with the strength of human muscle groups. Since the training sample does not contain the forecast sample, the prediction results are of general significance.

Table 5. Comparison between the prediction results of RBF network and BP network and the measured values.

Measured relative peak moment of knee flexor muscles	RBF network predicted value	BP network predicted value
1.81	1.9138	1.7841
1.83	1.7449	1.8486
1.83	1.8291	1.8370
1.79	1.8112	1.8308
1.81	1.8050	1.8044

4 Conclusion

This paper uses Mat lab’s neural network toolbox to establish a neural network model for predicting muscle strength of athletes. The prediction results indicate that this method has certain practical guidance significance, fully demonstrating the promising prospects of neural networks in the field of human muscle strength[11].

By comparing RBF networks with BP networks, it was found that in the grinding temperature prediction model, the RBF network has many advantages over traditional BP networks, such as higher precision, better generalization, and faster convergence speed. This also indicates that the advantages of RBF networks will lead to their wider application.

Neural network analysis shows that volleyball competitions for men require very high relative peak torques of the knee and ankle joint muscle groups. Additionally, some athletes have relatively low knee and ankle joint muscle group relative peak torques, which should be addressed through targeted strength training.

Introducing artificial neural network methods into the field of sports can make up for the shortcomings of traditional analytical methods. This model can also be used for the prediction and analysis of other human strength performance parameters.

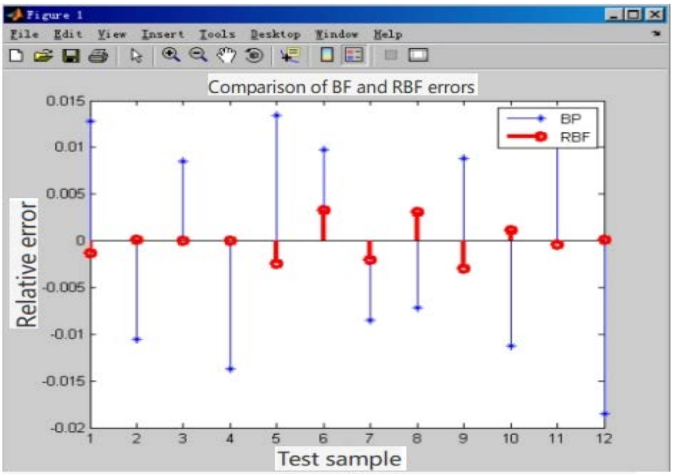

Fig.5. The prediction error comparison between RBF network and BP network.

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