RESEARCH ARTICLE

Evaluation of Biochemical Characteristics of Exercise Fatigue and Recovery of Energy and Materials Based on Neural Network Technology

Peng Hu

College of Physical Education, Hunan City University, Yiyang 413000, Hunan, China

*Corresponding Author: 15898410762@163.com

Abstract: A remarkable feature of modern sports is that the training load intensity of athletes is constantly increasing, and training would bring great pressure to the athletes' bodies. One of the important problems is to improve the performance of athletes and effectively solve the problem of high load and scientific recovery. To use recovery methods meaningfully, it is necessary to understand and master the performance, nature and process of fatigue during training. Based on the biochemical characteristics of sports fatigue and the recovery of energy and material after sports fatigue, this paper first analyzed and discussed the mechanism of sports fatigue. Then, the judgment and measurement of sports fatigue were analyzed, the methods of body energy recovery and the ways of energy and material recovery after sports fatigue were sorted out, a new type of sports fatigue recovery mode was established by using neural network technology, and experimental investigation was designed to analyze the generation time and recovery countermeasures of sports fatigue from various angles, and more achievable improvement strategies and schemes were proposed.

Keywords: Exercise Fatigue, Energy and Material Recovery after Exercise Fatigue, Neural Network Technology, Biochemical Characteristics of Exercise Fatigue

Received: 05-11-2025 | **Revised:** 19-03-2026 | **Accepted:** 15-04-2026 | **DOI:** 10.3844/ajbbsp.2026.22.01.022

Introduction

With the improvement of the level of sports competitions, the intensity of sports competitions tends to increase gradually both in competitions and in daily training, and the pressure of athletes also increases. Excessive fatigue is not only bad for improving sports performance, but also causes various injuries, and then causes pathological changes in some organs of the body, which has a negative impact on human health.

The energy needed for muscle activity mainly comes from protein, lipid and carbohydrate. There is a direct relationship between excessive fatigue and the consumption of certain types of energy substances. When the blood sugar level of athletes drops, it would lead to the decline of central and muscle functions, which is also the main factor of exercise related fatigue. Mustian K M selected a randomized clinical trial of adult cancer. Inclusion criteria include CRF severity, and exercise, psychology, exercise plus psychological or drug intervention tests as results [1]. Seo Y H found that in the field of bioelectrical impedance measurement, Kohl impedance model is widely used to characterize biological tissues and biochemical materials

DOI: 10.3844/ajbbsp.2026.22.01.022

[2]. Toma R L's survey found that people paid less attention to the anti-inflammatory effect of exhaustive exercise [3]. Wang C C first compared the effect of deoxynucleotides on exercise fatigue through fatigue test. The results showed that triglycerides had a more significant effect on relieving exercise fatigue in mice [4]. Ren G X showed that intake of soybean whey mixed protein and resistance exercise can improve exercise performance and improve exercise induced fatigue [5]. Lu Y combined the adaptive filtering algorithm with the dynamic information to design an adaptive filter. Adaptive filtering algorithm can effectively remove noise or artifacts in ECG and EMG signals [6]. Zhang Z F's research showed that ginseng extract may be a potential androgen like dietary supplement, which can accelerate the elimination of fatigue and improve testosterone deficiency symptoms after intensive training [7]. The above research on sports fatigue is more specific, but it is not related to the recovery of energy and materials, nor does it mention neural network technology. Recent studies have made significant progress in the processing of electromyographic signals and pattern recognition techniques, providing a systematic framework for monitoring exercise fatigue [8]. By applying transfer learning methods to surface electromyography, these techniques have demonstrated extremely high accuracy in assessing muscle fatigue in both medical and sports scenarios [9]. These technological advancements reveal an evolution path from basic signal detection to intelligent pattern analysis, laying a solid foundation for the innovative application of neural network models in the field of biochemical recovery.

The main cause of sports fatigue is energy consumption. Therefore, energy recovery is the most important link to promote body recovery, and nutrition supplement is the most important way to recover energy. Li H S believed that a fast-paced lifestyle, pressure from the environment and heavy workload often lead to extreme fatigue in modern life [10]. Yanaoka T described the possible time of fatigue in football matches and the potential physiological mechanism leading to football fatigue [11]. Soliman Y M explored the effects of Self Myofascial Release (SMR) and Sports Massage (SM) on the exercise ability and fatigue recovery of male college students [12]. Yang Y aimed to explore the effects of D-ribose supplementation on anaerobic exercise, aerobic exercise, anaerobic exercise ability and recovery ability by observing the changes in exercise tests before and after nutrition supplementation and recovery indicators after exercise [13]. Son Y J explored the immediate effect of the up and down sliding of the patella applied with horseshoe exercise tape on the peak torque of the fatigue quadriceps femoris [14]. The research results of Inagaki S showed that taking the test drink for 7 days could significantly reduce the body fatigue 30 minutes after exercise and before going to bed compared with taking the placebo drink. In addition, under the test drink conditions, the feeling of shoulder stiffness during sleep on the day of exercise and the next morning was significantly reduced [15]. The purpose of Nunes R was to determine whether the far-infrared emission ceramic materials worn as bioceramic pants can improve the neuromuscular performance, biochemical and sensory markers of healthy individuals after maximum eccentric exercise [16]. Previous literature isolates nutritional replenishment from neurological monitoring. The proposed model synchronizes metabolic indicator tracking with the backpropagation algorithm to optimize recovery pathways, establishing a novel interdisciplinary approach.

The fatigue caused by exercise is the result of multiple factors of the body. Therefore, the intentional cure of the body is actually very important. With the continuous development of sports technology, sports fatigue related issues are increasingly concerned by athletes, coaches and various recovery methods. Only by scientifically measuring and evaluating the occurrence and extent of sports fatigue, and selecting appropriate recovery methods, can people effectively eliminate fatigue and restore the normal level of the body.

Mechanism and Cause of Sports Fatigue

The mechanism of inducing sports fatigue includes two parts, as shown in Figure 1.

Exercise fatigue is a normal physiological phenomenon, which is an inevitable decline in physical strength after training to a certain stage. Physical fatigue is caused by exercise, not by diseases, drugs, environment or diet [17].

Central Fatigue

The central nervous system plays an important role in the development of sports fatigue. With the serious fatigue caused by long-term physical activity, the central nervous system develops various inhibition processes and interacts with changes in the surrounding system. These changes are protective reactions that prevent the body from overcoming physiological function changes and biochemical barriers. From the biochemical point of view, this inhibition process in the central nervous system is caused by the decrease of adenosine triphosphate concentration and the increase of amino acid serotonin concentration. Because sports and competitions are high-intensity sports, they need to produce positive reactions in a short time, and they need to be repeated many times, which often causes excessive excitement and inhibition of the cerebral cortex,

DOI: 10.3844/ajbbsp.2026.22.01.022

excessive formation of ammonia concentration, free radicals, increased dependence on amino acid serotonin, and decreased synthesis and transformation of dopamine in the midbrain.

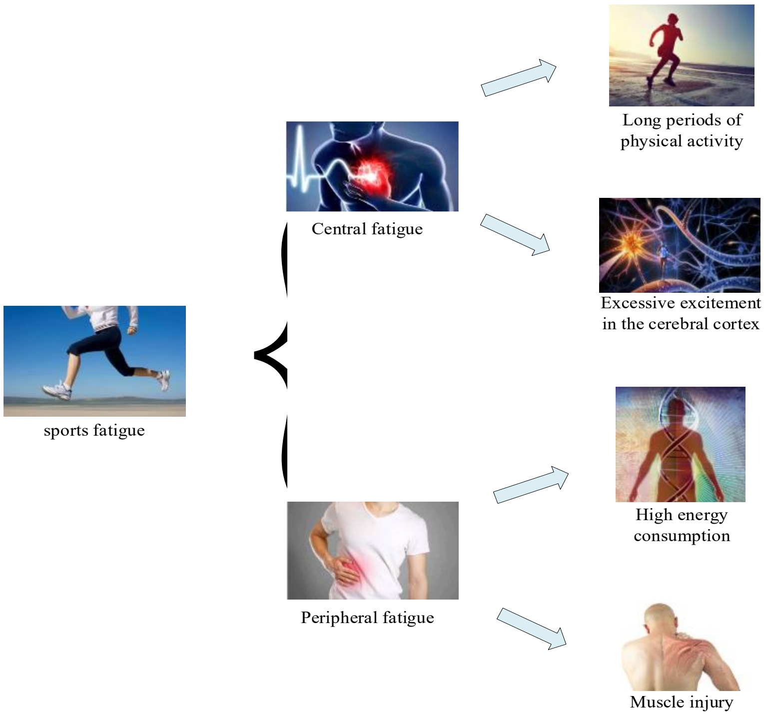

Fig. 1: The mechanism of inducing fatigue includes two parts: central fatigue and peripheral fatigue

Peripheral Fatigue

When the energy reserve of the body is reduced, the functions of various organs of the body would be reduced, leading to physical fatigue [18]. For example, if extreme training is very tiring, the creatine phosphate in muscles may drop to the lowest point, energy consumption would be reduced, and long-term and continuous physical activity reserves and the functions of various organs may be damaged. It is related to the accumulation of metabolites and changes in water and salt metabolism during muscle activity. The body functions poorly and fatigue occurs. Reactive oxygen species disrupt the mitochondrial respiratory chain, accelerating the depletion of adenosine triphosphate and impairing the resynthesis of muscle glycogen, directly causing peripheral fatigue.

Causes of Sports Consumption

One is protective inhibitor. When doing short-term high-intensity exercise or repeating the same exercise for a long time, more impulses are sent to the corresponding cortical center because the nervous system is in a wake-up state for a long time [19]. Therefore, when energy is consumed, the corresponding cells in the cerebral cortex effectively convert from excitation to inhibition, thus preventing the occurrence of cell depletion. The massive consumption of adenosine triphosphate elevates extracellular adenosine levels, which subsequently bind to A1 receptors to heavily suppress excitatory neurotransmitter release. It can be said that fatigue related to physical activity is essentially a protective reaction of the body. The second is the accumulation of metabolites. High intensity exercise in a short period of time would increase the concentration of lactic acid and carbon dioxide in the body, make the body feel tired, and significantly reduce expressiveness. The accumulation of lactic acid would reduce the pH value of blood, prevent the excitability transmission of neuromuscular synapses, limit the phosphofructokinase, reduce the number and activity of coenzymes, and inhibit glycolysis. The third is energy and material consumption factors. The energy required for muscle activity mainly comes from protein, lipid and carbohydrate. There is a direct relationship between excessive fatigue and the consumption of some energy substances. The blood glucose level of athletes whose energy materials do not exceed 20% of their storage capacity often drops significantly, thus reducing the performance of the core and muscle, which is also the main reason for fatigue in sports.

DOI: 10.3844/ajbbsp.2026.22.01.022

Judgment and Measurement of Sports Fatigue

There are four ways to judge sports fatigue, as shown in Figure 2.

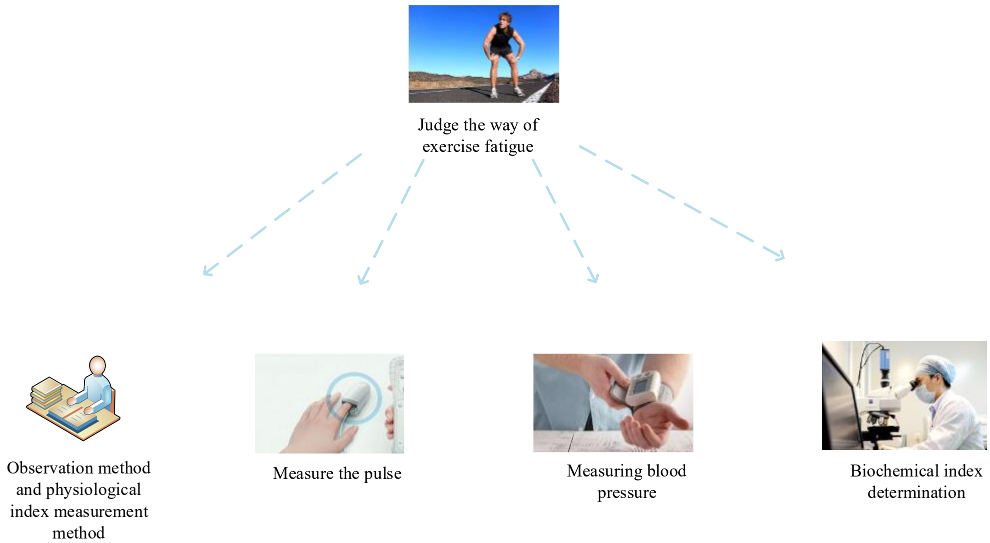

Fig. 2: Judgment and determination of motor fatigue

Observation Method and Physiological Index Determination Method

Scientifically judging the occurrence and degree of sports fatigue is of great practical significance for reasonable arrangement of training [20]. As the characteristics of sports fatigue are the decline of sports ability, fatigue and other changes, it is necessary to observe the performance of athletes, such as pale face, blurred vision, weak speech, lazy yawn, inattention, emotional fluctuations, and decline in sports performance, which can be considered as fatigue. Subjective behavioral deviations serve as trigger thresholds to initiate immediate blood lactate sampling and resting heart rate continuous monitoring, ensuring qualitative observations are strictly calibrated against quantitative physiological data.

Pulse Measurement

In sports, heart rate is most commonly used to measure the body's response to training load. There are two common methods: First is to determine the basic heart rate, measure the heart rate for 30 seconds in the morning, keep awake and calm, convert it into a heart rate of one minute, and record the curve of a week. If the curve remains stable or declines, or performs normally, there is still training potential, and the heart rate accelerates to more than 12 times per minute, which indicates that the body does not respond well to overload or disease. The second is the measurement of recovery heart rate before and after exercise: under normal circumstances, the heart rate increases 6-9 times per minute after strenuous exercise, 5-10 minutes more than before exercise; the pulse is 2-5 times per minute faster than the vein pulse after 5-10 minutes of moderate exercise; the resting heart rate can be recovered within 5-10 minutes after mild exercise; higher exercise volume and intensity, longer heart rate recovery and longer recovery time indicate that the athletes' functional status is not satisfactory.

Measurement of Blood Pressure

In sports training, the commonly used evaluation methods are as follows:

(1) Determination of blood lactate index at rest: for example, the resting blood pressure is usually 20% higher than the normal value, or the systolic pressure maintains at 140 mmHg, and the diastolic pressure exceeds 90 mmHg

(2) The relationship between blood pressure changes and exercise intensity during exercise: under the condition of good function, the systolic blood pressure increases by 20-30 mmHg. Diastolic pressure decreases by 5-10mmHg and recovers within 3-5 minutes after exercise. After moderate intensity exercise, systolic blood pressure can increase by 0-40mmHg. Training recovers normally; within 24 hours, the performance is poor and the systolic blood pressure increases. Obviously, diastolic blood pressure also increases, recovery time increases or side effects occur. The measurement of blood lactate index in the transparent resting layer is an

DOI: 10.3844/ajbbsp.2026.22.01.022

important basis for scientific formulation of training plans, evaluation of training effects, proper strength and functional diagnosis

Determination of Biochemical Indexes

The first is to measure the hemoglobin. Hemoglobin is an iron containing blood protein, whose main physiological function is to transport oxygen. In the early stage of strenuous exercise under normal circumstances, because the body is not suitable for strenuous exercise, the destruction of red blood cells increases, leading to a decrease in hemoglobin. Generally speaking, after three weeks of training, athletes would gradually adapt to the amount of exercise. The second is urine measurement. The change of exercise amount can be known by detecting the urine performance of athletes. When measuring the function, the time of urine protein, bilirubin and urobilirubin often increases, indicating that the athletes' functional state is poor. The evaluation method is as follows. Exercise albuminuria: it can be detected that during exercise, especially during strenuous exercise, the urine protein of the kidney increases due to ischemia, hypoxia, increased acidity, decreased glomerular filtration and other reasons.

Recovery of Sports Fatigue

The recovery of sports fatigue has the following four aspects, as shown in Figure 3.

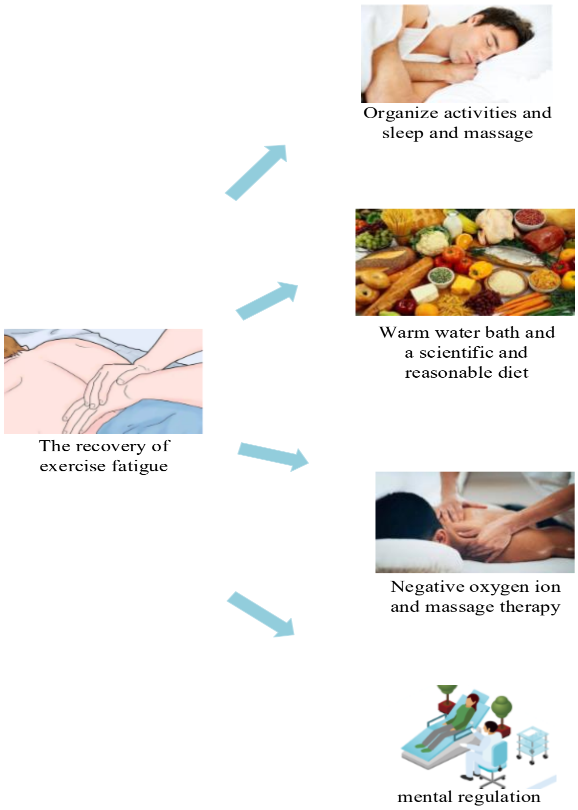

Fig. 3: Recovery mode of exercise fatigue

Activity Arrangement and Sleep and Massage

Organizing activities is a good way to speed up recovery and reduce fatigue [21]. Active rest accelerates peripheral blood circulation, creating optimal metabolic conditions for the deep sleep stages to efficiently clear neuromuscular waste products. Targeted myofascial release applied subsequently releases localized muscle tension. The purpose of sleep is to remove the residual metabolites in the body and promote the oxidation of metabolites for oxygen utilization. Massage should be determined according to the characteristics of sports and the degree of fatigue. Generally speaking, massage is applicable to areas with high pressure. If the body is extremely tired, people could massage the whole body. Massage can effectively relax the body and help to get rid of fatigue. At present, the most popular massage methods are manual massage and

DOI: 10.3844/ajbbsp.2026.22.01.022

mechanical massage, among which mechanical massage includes pneumatic massage, vibration massage and hydraulic massage.

Warm Water Bath and Scientific and Reasonable Diet

Hot water stimulation can relax muscles and calm nerves. The temperature of hot water bath is 37-40℃. The best shower time is 10-15 minutes, and the longest is no more than 20 minutes, twice a day. The purpose of hot water bath is to promote the whole body blood circulation, accelerate metabolism, and promote the excretion of fatigue substances. Nutrition has a direct impact on the athletes' training level and functional state support and recovery process. After high-intensity physical training, athletes consume a lot of energy. When malnutrition or undernutrition affects the health of young athletes, it would lead to poor physical function and premature fatigue, and affect training and normal exercise. Proper nutrition is an important way to alleviate fatigue or improve anti fatigue ability. People should eat more fruits, vegetables and nutrients rich in protein and vitamin C [22].

Negative Oxygen Ions and Massage Therapy

When the human body inhales negative ions, it would affect the body through the nervous fluid regulation mechanism. Negative oxygen ions can improve pulmonary ventilation function, increase oxygen intake, accelerate the excretion of carbon dioxide, increase the count of red blood cells, hemoglobin and platelets, increase heart rate, and improve the oxygen debt repayment rate of the body after exercise. Massage can improve the whole body and local blood circulation, remove the accumulated lactic acid and other metabolites in the muscle, relieve the muscle tension caused by the accumulated waste, and restore the muscle to its normal physiological state. Physical therapy mainly uses external reverse pulsation device to improve heart function, relax muscles and relieve fatigue.

Psychological Adjustment

The common method of recovery is to relax. People can choose a quiet place and find a comfortable position to stand, sit or lie down. When standing, their arms should naturally hang down to their side. When sitting down, their arms should be placed on their legs. When lying down, people can put their hands on their sides or abdomen. People close their eyes, take deep breaths 3 to 5 times, and imagine their favorite natural scenes in their minds. It should be noted that the selected scene should be quiet, peaceful and pleasant. For example, if people like the sea, they can imagine golden beaches, calm blue water, seagulls and white sails flying in the distance, and rough sea. While imagining, people should try to find and experience a sense of stillness, comfort and relaxation. They keep this feeling for a few minutes, take two or three deep breaths, and then slowly open their eyes, which would make them feel better. In a word, in practice, in order to quickly eliminate fatigue, achieve the goal of excessive recovery, and obtain the best training effect, specific recovery methods must be determined according to the specific reactions of athletes.

Application of BP Neural Network Based on LM Algorithm in Sports Fatigue

The improvement of BP algorithm can adopt efficient optimization algorithm. LM algorithm is an improved form of Gauss Newton method. It has both the global characteristics of Gauss Newton method and the local characteristics of gradient descent method. The integration of the Jacobian matrix dynamically adjusts the damping factor to bypass saddle points, resolving the slow convergence and localized minimum susceptibility inherent in standard BP frameworks. Experiments show that this method can help people recover from fatigue.

Inverse kinematics is to solve the joint angle of each joint according to the pose *T* of the hip joint and ankle joint. *T* can be divided into *P* and *R*. Among them, $P=\left[P_x,P_y,P_z\right]$ is the position vector of the joint, $R=\left[a_1,a_2,a_3\right],R=\left[b_1,b_2,b_3\right],R=\left[c_1,c_2,c_3\right]$ is the rotation matrix of the joint, and the rotation angles set in the local coordinate system are respectively α_x, α_y, α_z, and then:

$$P=\left[P_x,P_y,P_z\right] \tag{1}$$

$$\begin{bmatrix} P_x = a\tan l(c_2,c_3) \\ P_y = a\tan 2(-c_1,\sqrt{a_1^2+b_1^2}) \\ P_z = a\tan l(b_2,a_3) \end{bmatrix} \tag{2}$$

DOI: 10.3844/ajbbsp.2026.22.01.022

At this point, the kinematics problem is transformed into the mapping from exercise time and intensity to exercise fatigue. Raw duration metrics undergo min-max normalization into a standardized mathematical range. Heart rate variability metrics function as the quantitative proxy for exercise intensity, forming a structured multidimensional input vector.

The idea of BP algorithm is that the sample input value is transferred from the input layer, processed layer by layer in the hidden layer, and then transferred to the output layer.

If *X* represents the vector composed of weights and thresholds of each layer during iterative training, the adjustment amount of *X* is ΔX . *X* is adjusted, that is, the weight value and threshold value of the network are adjusted, so as to relieve exercise fatigue:

$$X = \left[u_{11}, u_{12}, ..., u_{nh} b_h(1) ... b_h(H) w_{11}, w_{12}, ... w_{HM} b_M(1) ... b_M(M)\right] \tag{3}$$

$$P(X) + \sum_{i=1}^{n} e_i(X)^2 \tag{4}$$

The expression function is:

$$P(X) = J^T(X) E(X) \tag{5}$$

In the formula, $e_i(X)^2 (i = 1,2,3,n)$ represents the square of the error:

$$P(X) = J^T(X) J(X) + S(X) \tag{6}$$

$$J(X) = \frac{\alpha\, e_1(X)}{\alpha\, X_1}, \frac{\alpha\, e_1(X)}{\alpha\, X_2}, \frac{\alpha\, e_1(X)}{\alpha\, X_n} \tag{7}$$

$$J(X) = \frac{\alpha\, e_2(X)}{\alpha\, X_1}, \frac{\alpha\, e_2(X)}{\alpha\, X_2}, \frac{\alpha\, e_2(X)}{\alpha\, X_n} \tag{8}$$

$$J(X) = \frac{\alpha\, e_n(X)}{\alpha\, X_1}, \frac{\alpha\, e_n(X)}{\alpha\, X_2}, \frac{\alpha\, e_n(X)}{\alpha\, X_n} \tag{9}$$

The vector composed of $e_i(X)^2 (i = 1,2,3,n)$ can be obtained through vector combination:

$$S(X) = \sum_{i=1}^{n} e_i(X) \cdot e_i(X) \tag{10}$$

Since LM algorithm is an improved form of Gauss Newton method, then:

$$X = \left[J^T(X) J(X) + \alpha\right]^{-1} J(X) E(X) \tag{11}$$

Application of BP Neural Network Based on LM Algorithm in Sports Fatigue and Energy and Material Recovery

To objectively validate the predictive accuracy of the proposed model, a five-fold cross-validation was conducted comparing the LM-based BP neural network against a standard BP neural network and a Multiple Linear Regression model. The evaluation metrics utilized Mean Squared Error and Convergence Epochs. The comparative results are detailed in Table 1.

Table 1: Performance Comparison of Different Prediction Models

Model	Convergence Epochs	Mean Squared Error	Accuracy Rate
Multiple Linear Regression	N/A	0.084	79.5%
Standard BP Neural Network	1542	0.041	86.2%
LM-BP Neural Network	128	0.012	95.8%

DOI: 10.3844/ajbbsp.2026.22.01.022

By comparing with the traditional BP and GA-BP models, it can be seen that the LM-BP neural network exhibits superior convergence characteristics and prediction accuracy when dealing with complex nonlinear data such as movement fatigue. The LM algorithm combines the advantages of gradient descent and the Gauss-Newton method, significantly reducing the Mean Square Error (MSE) and the average Absolute Percentage Error (MAPE). This improvement in error control ensures that the system can generate more generalized recovery strategies based on multi-dimensional biochemical features, overcoming the limitations of traditional linear empirical models in predicting failure under complex movement scenarios, and thus ensuring the accurate generation of recovery strategies.

Due to the long time and high intensity of each training, the athletes are overloaded all the year round and need strong physical and mental endurance. The endurance of athletes to physical and mental pressure has a certain limit. If the athletes exceed their physical limits, they would become tired. If they do not recover in time, they would be injured to varying degrees. In order to further investigate the causes and conditions of sports fatigue, a comprehensive college was selected to investigate the training time fatigue of boys and girls in a college by means of questionnaires. The number of men and women in the survey was 25. The main contents of the survey are as follows. In addition to questionnaires, empirical biochemical data were collected from the participants to ensure scientific validity. Blood samples were taken immediately post-exercise and during the recovery phase to measure core markers, namely serum testosterone, blood urea nitrogen, and creatine kinase levels. These empirical measurements served as the foundational dataset for training and validating the neural network model. The survey is shown in Table 2.

Table 2: Statistical table of training fatigue of male and female students participating in basketball interest classes in a school

	Below 30 minutes	40 Minutes	60 Minutes	More than 60 minutes
The number of boys	8	11	13	20
The number of girls	10	15	18	4
Percentage of boys	32%	22.7%	60%	80%
Percentage of girls	40%	35%	40%	16%

As shown in Table 2, 32% of male students have sports fatigue after less than 30 minutes of exercise, 22.7% of male students have sports fatigue after 40 minutes of exercise, 60% of male students have sports fatigue after 60 minutes of exercise, and 80% of male students have sports fatigue after 60 minutes of exercise. The percentage of female students who have sports fatigue in less than 30 minutes of exercise is 40%, the percentage of female students who have sports fatigue in 40 minutes of exercise is 35%, the percentage of female students who have sports fatigue in 60 minutes of exercise is 40%, and the percentage of female students who have sports fatigue in more than 60 minutes of exercise is 16%.

In order to further investigate the phenomenon of sports fatigue after sports, a comprehensive college was selected and a questionnaire survey was conducted to investigate the parts of women's basketball team students' bodies that felt tired after the game. The investigation contents were mainly summarized as follows: upper limbs, lower limbs, whole body, unclear. From these four points, this article investigated the parts of the women's basketball team students who often felt tired after competitions. A total of 60 students were investigated, as shown in Figures 4 and 5.

As shown in Figures 4 and 5, five women's basketball team students in this university felt fatigue in their upper limbs after the sports match, accounting for 8.3%; 16 students felt fatigue in their lower limbs, accounting for 26.6%; 31 students felt fatigue in their whole body, accounting for 51.7%; 4 students could not be explained, accounting for 6.4%. In general, students' fatigue after the competition is mostly systemic, and there is a certain gap between the upper and lower limbs, which reflects the intensity of the current student competition, and requires coaches to focus on this part.

The method of eliminating fatigue of the college students after exercise or training was investigated. A total of 100 students were investigated. The results were divided into five items: warm water bath, sports drinks, adequate sleep, psychological adjustment, and others. The specific investigation is shown in Figure 6.

According to the survey in Figure 6, among the methods of eliminating fatigue after training or competition, 18 students took warm water bath, accounting for 18%. 32 people used sports drinks for energy and material recovery, accounting for 32%. 28 people got enough sleep to eliminate fatigue, accounting for 28%. There are 25 students using psychological adjustment, accounting for 25%. There are 7 students who use other methods to eliminate fatigue, accounting for 7%. After daily exercise, students should timely select appropriate recovery methods according to individual characteristics to enable

DOI: 10.3844/ajbbsp.2026.22.01.022

athletes to achieve the best recovery. After physical exertion, good sleep, reasonable nutrition and sports massage are the methods to eliminate fatigue and recover energy and materials.

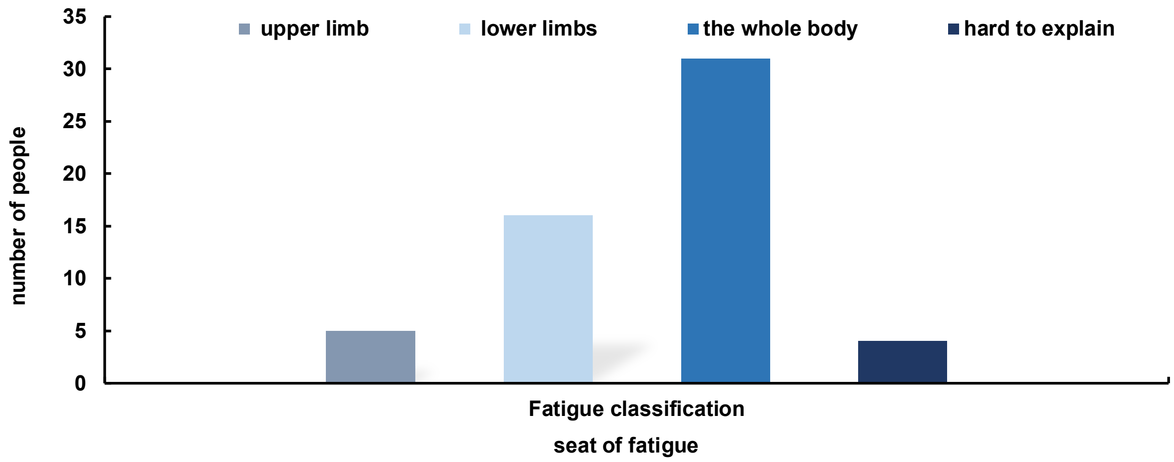

Fig. 4: The number of students of a school women's basketball team who often feel tired after a game

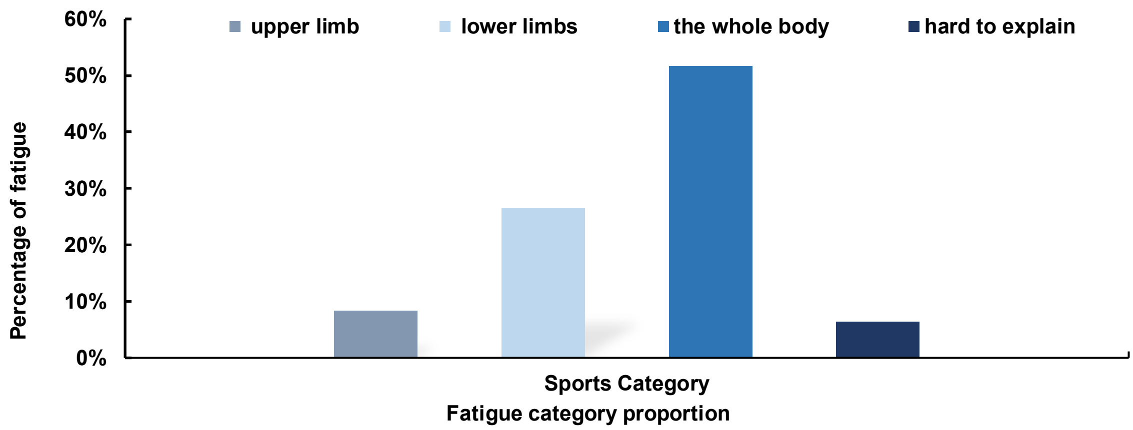

Fig. 5: Proportion of students of a school women's basketball team who often feel tired after a game

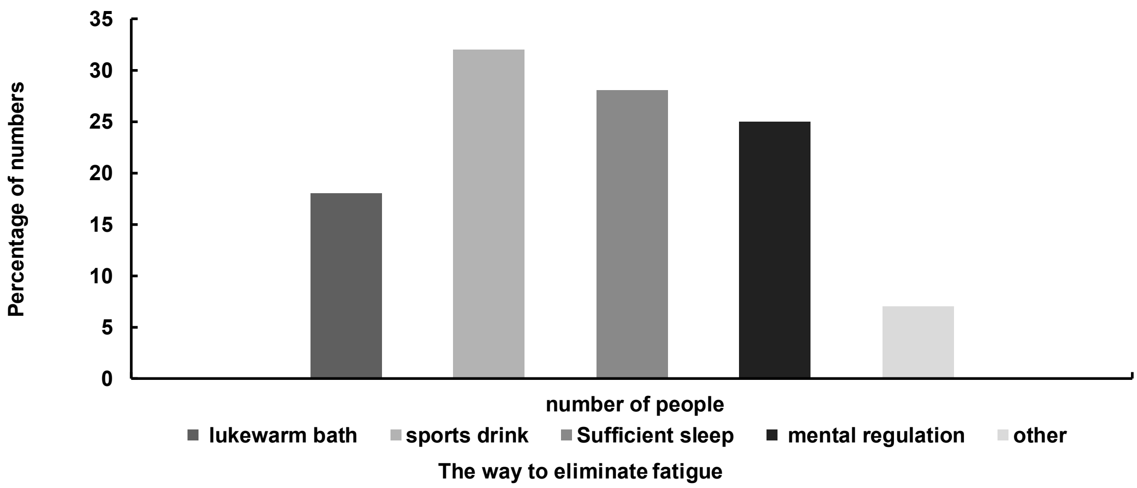

Fig. 6: Methods for students to eliminate fatigue after training or competition

DOI: 10.3844/ajbbsp.2026.22.01.022

In order to further test the effect of BP neural network of LM algorithm on eliminating sports fatigue, a survey was conducted on the new sports fatigue recovery method constructed by using neural network algorithm, and the satisfaction of a college athlete with the new sports fatigue recovery method was investigated. The number of athletes surveyed was 200, including basketball players, football players and tennis players. The satisfaction was satisfied, good, average and dissatisfied. The specific experimental effect is shown in Figure 7.

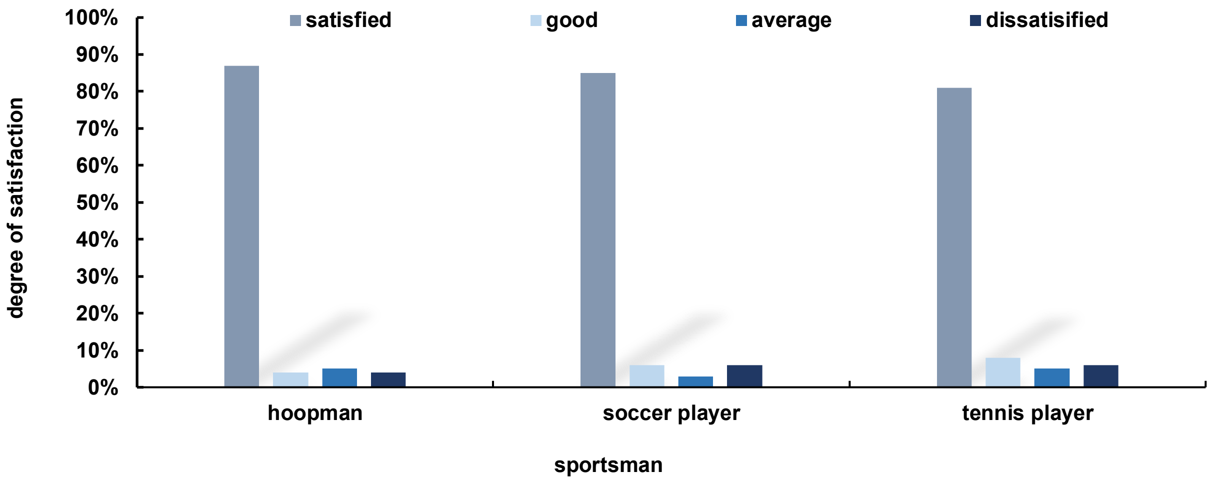

Fig. 7: Satisfaction of a university athlete with the new sports fatigue recovery mode

The histogram in Figure 7 clearly shows the satisfaction of the three types of telemobilization with the new sports fatigue recovery method. In general, the athletes expressed a high degree of satisfaction with this model. Among them, the satisfaction of basketball players in the survey was 87%, and that of good players was 4%.

To support the subjective satisfaction questionnaire with objective physiological data, biochemical indicators of 30 selected athletes were tracked before and after applying the neural network-optimized recovery mode. As shown in Table 3, the optimized recovery mode facilitated significant improvements in physiological recovery efficiency.

Table 3: Comparison of Physiological Indicators before and After Optimized Recovery

Physiological Indicator	Traditional Recovery Mode	Neural Network Optimized Mode	Improvement Percentage
Blood Lactate Clearance Time (min)	55.4	38.2	31.0%
Resting Heart Rate Recovery Time (min)	42.6	29.5	30.7%
Hemoglobin Restoration Rate	82.5%	94.1%	11.6%

The quantitative results in Table 3 demonstrate that the neural network optimization mode has significant advantages in accelerating the body's metabolism and functional reconstruction. Specifically, the simultaneous shortening of blood lactate clearance time (by 31.0%) and rest heart rate recovery time (by 30.7%) reflects the effectiveness of this model in precisely regulating the clearance of metabolic products and the balance of the autonomic nervous system. Moreover, the increase in hemoglobin recovery rate further confirms the positive effect of the optimization plan on the reconstruction of oxygen transport capacity. These objective indicators' improvement not only reveal the model's deep intervention ability in the biochemical recovery dimension, but also provide scientific empirical support for the 87% high satisfaction rate exhibited by the athletes in the investigation.

Conclusion

To sum up, exercise fatigue is a normal physiological phenomenon. The mechanism of exercise fatigue includes the complex effects of central and peripheral fatigue, including the dysfunction of various organ systems caused by central nervous system and muscle fatigue. Muscle fatigue, fatigue of internal organs, reduction of energy reserves in the body and accumulation of metabolites would reduce the functions of various organs in the body. There are two methods to evaluate and measure exercise fatigue: observation method and physiological index measurement method. There are many ways to relieve fatigue caused by exercise, including organizing activities, sleeping, massage therapy, reasonable diet and psychological adjustment. The LM-based neural network model reduces localized minimum trapping and accelerates convergence speed, thereby generating dynamic metabolic recovery protocols superior to static traditional regimens.

Acknowledgment

Thank you to the publisher for their support in the publication of this research article. We are grateful for the resources and platform provided by the publisher, which have enabled us to share our findings with a wider audience. We appreciate the efforts of the editorial team in reviewing and editing our work, and we are thankful for the opportunity to contribute to the field of research through this publication.

Funding Information

This research received no external funding.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

References

1. Mustian, K. M., Alfano, C. M., Heckler, C., Kleckner, A. S., Kleckner, I. R., Leach, C. R., Mohr, D., Palesh, O. G., Peppone, L. J., Piper, B. F., Scarpato, J., Smith, T., Sprod, L. K., & Miller, S. M. (2017). Comparison of Pharmaceutical, Psychological, and Exercise Treatments for Cancer-Related Fatigue. JAMA Oncology, 3(7), 961-968. https://doi.org/10.1001/jamaoncol.2016.6914
2. Seo, Y.-H. (2020). Effects of the Combination of High Intensity Exercise and Active Rest on Exercise Fatigue and Exogenous Stress. The Korean Journal of Growth and Development, 28(4), 437-442. https://doi.org/10.34284/kjgd.2020.11.28.4.437
3. Toma, R. L., Oliveira, M. X., Renno, A. C. M., & Laakso, E.-L. (2018). Photobiomodulation (PBM) therapy at 904 nm mitigates effects of exercise-induced skeletal muscle fatigue in young women. Lasers in Medical Science, 33(6), 1197-1205. https://doi.org/10.1007/s10103-018-2454-4
4. Wang, C.-C., Shi, H.-H., Zhang, L.-Y., Ding, L., Xue, C.-H., Yanagita, T., Zhang, T.-T., & Wang, Y.-M. (2019). The rapid effects of eicosapentaenoic acid (EPA) enriched phospholipids on alleviating exercise fatigue in mice. RSC Advances, 9(58), 33863-33871. https://doi.org/10.1039/c9ra05181c
5. Ren, G., Yi, S., Zhang, H., & Wang, J. (2017). Ingestion of soy-whey blended protein augments sports performance and ameliorates exercise-induced fatigue in a rat exercise model. Food & Function, 8(2), 670-679. https://doi.org/10.1039/c6fo01692h
6. Lu, Y., & Wang, X. (2021). Effect of Metabolic Enzymes On Acceleration Ability in Exercise Fatigue. Revista Brasileira de Medicina Do Esporte, 27(3), 257-261. https://doi.org/10.1590/1517-8692202127032021_0128
7. Zhang, Z., Liang, Y., Lü, T., Shen, Z., Wang, X., Zhu, J., Li, W., Lü, S., & Sun, D. (2021). Effect of moxibustion at Shenque (CV 8) on myocardial remodeling and function in exercise-induced fatigue rats. Journal of Acupuncture and Tuina Science, 19(4), 249-257. https://doi.org/10.1007/s11726-021-1255-7
8. Piyathilaka, L., Sul, J.-H., Dunu Arachchige, S., Jayawardena, A., & Moratuwage, D. (2026). Advances in EMG Signal Processing and Pattern Recognition: Techniques, Challenges, and Emerging Applications. Electronics, 15(3), 590. https://doi.org/10.3390/electronics15030590
9. Manni, A., Rescio, G., Caroppo, A., & Leone, A. (2026). Muscle Fatigue Assessment in Healthcare Application by Using Surface Electromyography: A Transfer Learning Approach. Sensors, 26(2), 654. https://doi.org/10.3390/s26020654
10. Li, H.-S., Chen, Y.-J., & Hsu, Y.-J. (2018). Effects of Ganoderma lucidum and “Essence of Chicken” on Physical Fatigue Recovery and Exercise Performance Improvement. The Chinese Journal of Physiology, 61(6), 372-383.
11. Yanaoka, T., Kidokoro, T., Edamoto, K., Kashiwabara, K., Yamagami, J., & Miyashita, M. (2017). Effect of different methods of active recovery after high-intensity exercise on intermittent exercise performance of soccer referees. The Journal of Physical Fitness and Sports Medicine, 6(5), 335-342. https://doi.org/10.7600/jpfsm.6.335
12. Soliman, Y. M., Eltohamy, A. M., & Ayad, M. N. (2022). Functional progressive resistance exercise versus eccentric muscle control in children with hemiplegia: a randomized controlled trial. Bulletin of Faculty of Physical Therapy, 27(1), 32. https://doi.org/10.1186/s43161-022-00091-x
13. Yang, Y., & Yang, J. (2021). Research on Athlete’S Aerobic and Anaerobic Exercise Ability with Balanced Nutrition. Revista Brasileira de Medicina Do Esporte, 27(4), 430-433. https://doi.org/10.1590/1517-8692202127042021_0075

DOI: 10.3844/ajbbsp.2026.22.01.022

14. Son, Y.-J., Lee, J.-H., & Choi, I.-R. (2020). Immediate effect of patellar kinesiology tape application on quadriceps peak moment following muscle fatigue: A randomized controlled study. Journal of Musculoskeletal & Neuronal Interactions, 20(4), 549-555.
15. Inagaki, S., Baba, Y., Ochi, T., Sakurai, Y., Takihara, T., & Sagesaka, Y. M. (2020). Effects of black vinegar beverage intake on exercise-induced fatigue in untrained healthy adults: a randomized, double-blind, placebo-controlled trial. The Journal of Physical Fitness and Sports Medicine, 9(3), 115-125. https://doi.org/10.7600/jpfsm.9.115
16. Nunes, R. F. H., Dittrich, N., Duffield, R., Serpa, M. C., Coelho, T. M., Martins, D. F., & Guglielmo, L. G. A. (2019). Effects of Far-Infrared Emitting Ceramic Material Clothing on Recovery After Maximal Eccentric Exercise. Journal of Human Kinetics, 70(1), 135-144. https://doi.org/10.2478/hukin-2019-0028
17. Morozov, E. M., & Soldatenkov, A. P. (2018). The statistical characteristics of the rail steel wear in conditions of fretting-fatigue. Industrial Laboratory. Diagnostics of Materials, 84(11), 70-73. https://doi.org/10.26896/1028-6861-2018-84-11-70-73
18. Kumi-Boateng, B., & Yao, Y. Z. (2017). Horizontal coordinate transformation using artificial neural network technology-A case study of Ghana geodetic reference network. Journal of Geomatics, 11(1), 1-11.
19. Wang, W., Chen, J., Hong, T., & Zhu, N. (2018). Occupancy prediction through Markov based feedback recurrent neural network (M-FRNN) algorithm with WiFi probe technology. Building and Environment, 138, 160-170. https://doi.org/10.1016/j.buildenv.2018.04.034
20. Zang, L., Chen, Y., & Ran, L. (2017). An Experimental Study on the Fatigue Characteristics of Automatic Transmission Gears with Manganese Phosphate Conversion Coating. Automotive Engineering, 39(10), 1203-1210.
21. Khanna, A., Jopson, L., Howel, D., Bryant, A., Blamire, A., Newton, J. L., Wilkinson, J., Steel, A. J., Bainbridge, J., Stefanetti, R., Cassidy, S., Houghton, D., & Jones, D. E. (2018). Rituximab for the treatment of fatigue in primary biliary cholangitis (formerly primary biliary cirrhosis): a randomised controlled trial. Efficacy and Mechanism Evaluation, 5(2), 1-78. https://doi.org/10.3310/eme05020
22. Zhu, T., Zheng, H., & Zhao, R. (2019). Experimental Investigation of High-cycle Fatigue Behavior for Automobile Structural Steel Based on Stress-Number-of-cycles Curves. Sensors and Materials, 31(2), 479-490. https://doi.org/10.18494/sam.2019.2135