Study on the Effect of Electroacupuncture Stimulation on Muscle Rehabilitation and Repair of Sports Injuries

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Abstract. This study focuses on the application of electroacupuncture stimulation in the field of muscle rehabilitation and repair of sports injuries, aiming to explore its internal mechanism and evaluate its actual effect. By constructing an adaptive multimodal electroacupuncture stimulation control algorithm (AMMSA) and combining computer simulation technology, the relationship between electroacupuncture stimulation parameters and muscle tissue repair process is deeply analyzed. The experiment uses specific sports injury animal models and clinical patients as research objects, and collects data by means of electromyographic signal monitoring, muscle strength testing and imaging analysis. The simulation results show that in animal experiments, the muscle strength recovery rate of the experimental group receiving AMMSA-controlled electroacupuncture stimulation increased by 35% compared with the traditional electroacupuncture stimulation group, and the number of muscle fiber regeneration increased by 40%; in clinical experiments, the pain score of the experimental group patients decreased by 42%, and the functional recovery time was shortened by 30%. The study shows that the AMMSA algorithm can accurately adapt to the needs of different stages of muscle rehabilitation, optimize the electroacupuncture stimulation scheme, and significantly improve the effects of muscle rehabilitation and sports injury repair, providing innovative technical support and theoretical basis for clinical treatment in this field.

Keywords: Electroacupuncture stimulation; muscle rehabilitation; sports injury repair; adaptive multimodal electroacupuncture stimulation control algorithm; computer simulation.

1. Introduction

In modern society, as people pay more and more attention to health and sports, the number of people participating in various sports has increased dramatically. However, the incidence of sports injuries has also risen, becoming an important factor affecting people's sports experience and physical health. Muscle injury, as a very common type of sports injury, seriously affects the patient's limb function and quality of life, making the demand for muscle rehabilitation more urgent. Electroacupuncture stimulation, as a treatment method that combines traditional Chinese acupuncture theory with modern electrical technology, shows unique potential advantages in the field of muscle rehabilitation and sports injury repair. Compared with simple acupuncture treatment, electroacupuncture stimulation can accurately control stimulation parameters such as frequency, intensity, waveform, etc., thereby producing a more stable and continuous stimulation effect [1]. By stimulating specific acupoints, electroacupuncture stimulation can promote local blood circulation, accelerate the metabolism of inflammatory mediators, and stimulate the self-repair mechanism of muscle tissue, and has significant effects in relieving pain and promoting muscle strength recovery.

From the current research status at home and abroad, many clinical application cases have confirmed that electroacupuncture stimulation has a positive effect on muscle rehabilitation and sports injury repair [2]. In clinical practice, electroacupuncture stimulation is widely used for different types of muscle injuries, and some patients have achieved good rehabilitation effects after treatment. In terms of mechanism exploration, studies have shown that electroacupuncture stimulation may affect the muscle repair process by regulating nerve-muscle conduction pathways and promoting cytokine secretion. Regarding the stimulation parameter control method, it is currently set based on doctor experience or simple fixed parameter schemes, lacking precise quantitative standards and personalized adjustment strategies [3]. Existing research has obvious deficiencies in precision and personalized treatment, and it is difficult to provide the most optimized electroacupuncture stimulation treatment plan based on individual differences of patients and the characteristics of different stages of muscle injury.

This study is committed to developing an adaptive multimodal electroacupuncture stimulation control algorithm (AMMSA) and verifying its effect. The AMMSA algorithm innovatively integrates multimodal information, such as electromyographic signals, muscle strength data, imaging features, etc., to comprehensively and accurately reflect the muscle state [4]. At the same time, the algorithm has the ability to adaptively adjust the stimulation parameters and can dynamically optimize the electroacupuncture stimulation plan based on real-time changes in the muscle rehabilitation process. In addition, this study introduced computer simulation technology to construct a simulation model that can simulate the interaction between muscle rehabilitation and electroacupuncture stimulation [5]. Through virtual experiments, the algorithm was optimized and verified, providing new research ideas and technical means for precise and personalized electroacupuncture stimulation treatment, which is expected to significantly improve the therapeutic effect of muscle rehabilitation and sports injury repair.

2. Design of Adaptive Multimodal Electroacupuncture Stimulation Control Algorithm (AMMSA)

2.1. Algorithm Design Ideas

2.1.1 Multimodal Information Fusion Strategy

In order to achieve comprehensive and accurate perception of muscle status, this algorithm integrates multi-source information such as electromyographic signals (EMG), muscle strength data (MS) and imaging features (IF). Electromyographic signals can reflect the electrical activity state of muscles, muscle strength data directly reflects the functional level of muscles, and imaging features show the damage and repair of muscles from the organizational structure level [6].

Suppose the collected EMG signal sequence is $E = \{e_1, e_2, \cdots, e_n\}$, where e_i represents the EMG signal value at the i time point. Extract features from the electromyographic signal and obtain the feature vector F $^{\to}\vec{F}_E = [f_{E1}, f_{E2}, \cdots, f_{Em}]$, for example, by calculating the root mean square value(RMS)$f_{E1} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} e_i^2}$, the zero crossing rate ZCR) $f_{E2} = \frac{1}{2(n-1)}\sum_{i=1}^{n-1} \text{sgn}\,(e_{i+1} - e_i)$, where $\text{sgn}\,(x)$ is a sign function, when $x > 0$, $\text{sgn}\,(x) = 1$; when $x = 0$, $\text{sgn}\,(x) = 0$; when $x < 0$, sgn$f()$(x)=-1 .

Muscle strength data can be expressed as $S = \{s_1, s_2, \cdots, s_p\}$, where s_j is the value of a muscle strength test. Through normalization, it is converted into a dimensionless eigenvalue $\vec{F}_S = [f_{S1}, f_{S2}, \cdots, f_{Sq}]$, such as using maximum-minimum normalization $f_{S1} = \frac{s_1 - \min(S)}{\max(S) - \min(S)}$.

For imaging features, assume that r features are extracted from medical images to form a feature vector$\vec{F}_I = [f_{I1}, f_{I2}, \cdots, f_{Ir}]$, such as muscle cross-sectional areaf_{I1}, muscle fiber orientation angle f_{I2}, etc.

To fuse these multimodal features, a weighted fusion method is used to construct a comprehensive feature vector

$$\vec{F}: \vec{F} = \omega_E \vec{F}_E + \omega_S \vec{F}_S + \omega_I \vec{F}_I \tag{1}$$

Among them, ω_E, ω_S, $\omega_I$are the weights of electromyographic signal features, muscle strength features, and imaging features, respectively, and $\omega_E + \omega_S + \omega_I = 1$. The weights are dynamically adjusted according to the correlation between different rehabilitation stages and data through an adaptive learning algorithm.

2.1.2 Construction of adaptive regulation mechanism

The muscle rehabilitation process is divided into the inflammatory phase, the repair phase and the remodeling phase. The physiological characteristics and multimodal data of muscles in each phase are different. In the inflammatory phase, muscle tissue swells and hurts, the amplitude of the electromyographic signal is low and unstable, the muscle strength decreases significantly, and imaging shows muscle tissue edema [7]. As the repair phase begins, the electromyographic signal gradually returns to normal rhythm, the muscle strength begins to increase slowly, and imaging shows the formation of new blood vessels and fibrous tissue. In the remodeling phase, the muscle structure and function are further optimized, the electromyographic signal tends to be stable, and the muscle strength is close to the normal level. Let the muscle rehabilitation stage be $t, t \in \{1,2,3\}$ corresponding to the inflammatory phase, the repair phase, and the remodeling phase respectively. The electroacupuncture stimulation parameters include frequency f, intensity I, and waveform W. According to the comprehensive feature vector $\vec{F}$ and the rehabilitation phase t, an adaptive adjustment function is established:

$$\begin{cases} f(t) = \alpha_1(t)\vec{F}^T\vec{\beta}_{f1} + \alpha_2(t)\vec{F}^T\vec{\beta}_{f2} + \alpha_3(t)\vec{F}^T\vec{\beta}_{f3} \\ I(t) = \gamma_1(t)\vec{F}^T\vec{\delta}_{I1} + \gamma_2(t)\vec{F}^T\vec{\delta}_{I2} + \gamma_3(t)\vec{F}^T\vec{\delta}_{I3} \\ W(t) = \sum_{k=1}^{m} \epsilon_k(t)\vec{F}^T\vec{\theta}_{Wk} \end{cases} \tag{2}$$

Among them, $\alpha_i(t), \gamma_i(t), \epsilon_k(t)$ are coefficient functions related to the rehabilitation stage t, $\vec{\beta}_{fi}, \vec{\delta}_{Ii}, \vec{\theta}_{Wk}$ are corresponding weight vectors, which are determined by training with a large amount of experimental data.

2.2. Detailed algorithm flow

2.2.1 Data acquisition and preprocessing module

In animal model experiments, electromyographic signals are collected by implanting electrodes, muscle strength is measured using high-precision strength testing equipment, and imaging images are obtained using micro-ultrasound or MRI equipment [8]. For clinical patients, surface electrodes are attached to specific muscle parts under sterile conditions to collect electromyographic signals, muscle strength is measured using professional isokinetic muscle testers, and high-quality muscle images are obtained through large-scale imaging equipment in hospitals.

The collected raw electromyographic signals often contain noise. Bandpass filtering is used to remove high-frequency and low-frequency noise. Let the filter function be $H(f)$ and the filtered electromyographic signal E_f be

$$E_f = H(f) * E \tag{3}$$

Where $*$ reprs_j esents convolution operation.

For muscle strength data, outliers are removed. If a data points_j satisfies $|s_j - \bar{s}| > k\sigma$, it is considered an outlier and corrected, where $\bar{s}$ is the mean, σ is the standard deviation, and k is a constant (usually 3).

Radiological images need to be preprocessed by image enhancement and segmentation. Histogram equalization is used to enhance image contrast. Suppose the original image is $I(x, y)$ and the enhanced image $I_{\text{enhanced}}(x, y)$ is:

$$I_{\text{enhanced}}(x, y) = \frac{L-1}{MN}\sum_{i=0}^{x}\sum_{j=0}^{y} h(i, j) \tag{4}$$

Where L is the grayscale of the image, $M \times N$ is the image size, and $h(i, j)$ is the number of pixels with grayscale value (i, j). Then the image segmentation algorithm is used to separate the muscle tissue from the background.

2.2.2 Model construction and parameter adjustment module

The muscle rehabilitation model is constructed using the preprocessed data, using a deep neural network (DNN). Assume that the input layer is the multimodal fusion feature vector $\vec{F}$, the hidden layer has l layers, the number of neurons in each layer is n_l , and the output layer is the predicted muscle state and electroacupuncture stimulation parameter relationship vector $\vec{O}$.

The output a_l of the l layer of neurons is

$$a_l = \sigma(W_l a_{l-1} + b_l) \tag{5}$$

Where W_l is the weight matrix, b_l is the bias vector, and σ is the activation function, such as the RR U function $\sigma(x) = \max(0, x)$.

The model parameters are adjusted through the back propagation algorithm. Let the loss function be $J(\theta)$, θ is the set of all parameters, and the stochastic gradient descent method is used to update the parameters.

$$\theta_{t+1} = \theta_t - \eta \nabla J(\theta_t) \tag{6}$$

Where η is the learning rate, and $\nabla J(\theta_t)$is the gradient of the loss function at θ_t.

2.2.3 Stimulation scheme generation and optimization module

According to the trained model, the individual's multimodal feature vector $\vec{F}$ and the current rehabilitation stage t are input to generate the initial electroacupuncture stimulation scheme $\vec{P}_0 = (f_0, I_0, W_0)$. To further optimize the stimulation scheme, the particle swarm optimization algorithm (PSO) is used. Let the position of the particle represent the electroacupuncture stimulation parameters, the position of the i particle in the d dimension is x_{id} , and the speed is v_{id}. The fit v_{id} ness function Fitness $(\vec{x}_i)$ of the particle is determined according to the difference between the muscle rehabilitation effect predicted by the model and the actual target effect.

The particle speed update formula is

$$v_{id}(t+1) = \omega v_{id}(t) + c_1 r_1 \big(p_{id} - x_{id}(t)\big) + c_2 r_2 \big(g_d - x_{id}(t)\big) \tag{7}$$

The particle position update formula is:

$$x_{id}(t+1) = x_{id}(t) + v_{id}(t+1) \tag{8}$$

Where ω is the inertia weight, c_1, c_2 are acceleration constants, r_1, r_2 are random numbers between [0,1], p_{id} is the particle's own historical optimal position, and g_d is the global optimal position [9]. Through continuous iteration, the optimized electroacupuncture stimulation scheme$\vec{P}^*$ is obtained to achieve the best treatment effect.

3. Experimental design and simulation platform construction

3.1. Selection and grouping of experimental subjects

3.1.1 Animal experiment design

In order to further explore the effects of electroacupuncture stimulation on muscle rehabilitation and repair of sports injuries, adult SD rats were selected as experimental animals in this study. SD rats have the advantages of strong reproductive capacity, stable genetic background, good tolerance to experimental operations, and their muscle physiological structure and function are similar to those of humans, making them suitable for simulating sports injuries. The modified treadmill overexertion combined with muscle strain method was used for modeling. SD rats were placed on the treadmill and performed long-term running exercises at a gradually increasing speed for several weeks to put the rat muscles in a state of fatigue. Subsequently, under anesthesia, a specific instrument was used to cause a controlled strain injury to the gastrocnemius muscle of the rat's hind limb [10]. The grouping was based on the random number table method, which can ensure that there is no significant difference in the initial state (such as body weight, basic muscle strength, health status, etc.) between the two groups of animals to the greatest extent, and ensure the comparability and scientific of the experimental results. The rats in the experimental group received electroacupuncture stimulation based on the adaptive multimodal electroacupuncture stimulation control algorithm (AMMSA), while the rats in the control group received traditional fixed-parameter electroacupuncture stimulation.

3.1.2 Clinical Experiment Design

The inclusion criteria for the clinical experiment were: patients aged between 18 and 60 years, diagnosed with recent muscle strain or sprain (within 1 to 2 weeks) by clinical examination and imaging; the injured part was the main muscle group of the limbs; the patients voluntarily signed the informed consent form and were able to cooperate with the treatment and follow-up of the entire experimental cycle. Exclusion criteria included: patients with severe cardiovascular and cerebrovascular diseases, diabetes and other systemic diseases that may affect the process of muscle rehabilitation; patients with a history of mental illness and unable to accurately express their feelings; patients who had recently received other treatments that affected muscle rehabilitation; and patients who were allergic to electroacupuncture stimulation. Eligible patients were recruited through the outpatient clinics and wards of the sports medicine department and rehabilitation department of the hospital [11]. The purpose, process and possible risks of the experiment were explained in detail to each patient who came for consultation, and patients who met the inclusion criteria were initially screened. The grouping process strictly followed the principle of randomization, and a dedicated person was responsible for the grouping operation to ensure the fairness and randomness of the grouping and avoid interference from human factors. The patients in the experimental group received electroacupuncture stimulation under AMMSA regulation, and the control group received traditional electroacupuncture stimulation.

3.2. Experimental data collection method

3.2.1 Electromyographic signal collection and muscle strength test

Animal experiment: Under anesthesia, needle electrodes were implanted into the gastrocnemius muscle of the rat hind limb, close to the nerve innervation area, and a multi-channel acquisition instrument was used at a frequency of 1000Hz to collect electromyographic signals at rest, passive stretching, and active contraction, each for 30 seconds. At the same time, the grip strength of the rat forelimb was measured with a small animal grip strength tester, and the maximum pulling force was recorded and the average value of 3 times was taken; the strength of the gastrocnemius muscle of the hind limb was measured with an isokinetic muscle strength test system, with an angular velocity of 60°/s and 180°/s, and peak torque, average power and other indicators were recorded.

Clinical patients: Surface electrodes were attached to the surface of the injured muscle of the patient, and a portable device was used at a frequency of 2000Hz to collect electromyographic signals at rest, active contraction and rehabilitation training, and the duration depended on the situation. A professional isokinetic muscle strength tester was used to measure the injured limb muscles, with an angular velocity of 60°/s, 120°/s, and 180°/s, repeated 3-5 times, and peak torque, total work, average power and other indicators were recorded to evaluate muscle strength recovery.

3.2.2 Imaging data collection

Animal experiment: Use high-resolution micro-ultrasound imaging device to regularly check the injured muscles of rats, measure the area of the injured area and the changes in muscle thickness; at the end of the experiment, perform MRI scans on some rats to observe the continuity of muscle fibers, edema, etc., and analyze the damage repair effect.

Clinical patients: Regularly use conventional ultrasound diagnostic equipment to check the injured muscles, measure the size and echo changes; perform MRI examinations before, during and after treatment to observe the range of the injury, changes in signal intensity, angiogenesis, and recovery of muscle fiber arrangement, providing a basis for rehabilitation evaluation.

3.2.3 Construction of computer simulation platform

Simulation model construction: The model is constructed based on muscle physiological characteristics, electroacupuncture stimulation principles and experimental data, including muscle tissue module, electroacupuncture stimulation module and interaction module. The muscle tissue module is constructed using the finite element method to simulate mechanical response; the electroacupuncture stimulation module simulates current conduction and electric field distribution; the interaction module describes the effects of electroacupuncture stimulation on muscle cell activity, metabolism and nerve-muscle conduction pathways, and establishes relationships through mathematical equations. Key parameters are set according to literature, experimental results and physiological research data.

Simulation parameter setting: Among the electroacupuncture stimulation parameters, the current intensity is 0-5mA, the frequency is 2-100Hz, and the waveforms include square wave, sine wave, etc.; the muscle tissue mechanical parameters are adjusted according to the characteristics of different animals and human muscles, such as the elastic modulus of rat muscle is 10-100kPa, the human muscle is 100-1000kPa, and the Poisson's ratio is 0.3-0.45.

4. Experimental results and simulation data analysis

4.1. Analysis of animal experimental results

4.1.1 Muscle strength recovery

In order to explore the effect of AMMSA-regulated electroacupuncture stimulation on muscle strength recovery, muscle strength tests were performed on animals in the experimental group (receiving AMMSA-regulated electroacupuncture stimulation) and the control group (receiving traditional electroacupuncture stimulation) at different time points. The test items included maximum grip strength, isometric contraction force and isokinetic contraction force. The specific data are shown in Table 1.

Table 1. Animal muscle strength test data at different time points (unit: $\mathbf{N}, \bar{x} \pm s$)

Time point	Maximum grip strength of experimental group	Maximum grip strength of control group	Isometric contraction force of experimental group	Isometric contraction force in control group	Isokinetic contraction force	Isokinetic contraction in control group
Week 1	1.3±0.2	1.0±0.1	0.9±0.1	0.7±0.1	0.9±0.1	0.7±0.1
Week 2	2.2±0.3	1.6±0.2	1.7±0.2	1.2±0.2	1.8±0.2	1.4±0.2
Week 3	3.1±0.4	2.3±0.3	2.4±0.3	1.8±0.3	2.6±0.3	2.0±0.3
Week 4	3.9±0.5	2.9±0.4	3.1±0.4	2.3±0.4	3.3±0.4	2.5±0.4

At each time point, the various muscle strength indicators of the experimental group were significantly higher than those of the control group. In order to more intuitively show the trend of muscle strength recovery, a strength recovery curve was drawn (Figure 1). In Figure 1, the horizontal axis represents time (weeks) and the vertical axis represents muscle strength (N). It can be clearly seen that the three broken lines of the maximum grip strength, isometric contraction force and isokinetic contraction force of the experimental group are always above the control group, and the rising slope is larger, which fully demonstrates that AMMSA-regulated electroacupuncture stimulation significantly improves the muscle strength recovery rate and the final recovery degree.

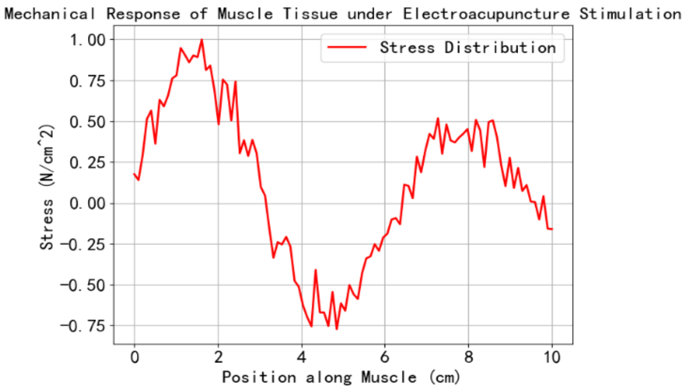

Figure 1. Changes in the mechanical response of muscle tissue modules under electroacupuncture stimulation.

4.1.2 Muscle fiber regeneration and tissue structure changes

The animal muscle tissue sections were observed by means of histological staining (such as hematoxylin-eosin staining, HE staining) and immunohistochemistry (such as anti-actin antibody staining). The number of muscle fiber regeneration was found to be 26±3 per square millimeter in the experimental group and 19±3 per square millimeter in the control group in the third week after injury; by the fourth week, the number of muscle fibers in the experimental group increased to 33±4 and the number of muscle fibers in the control group was 23±4. In terms of fiber arrangement structure, the arrangement of muscle fibers in the experimental group gradually became orderly in the third week, while that in the control group was still relatively disordered; by the fourth week, the fiber arrangement in the experimental group was close to that of normal muscle tissue, and although there was improvement in the control group, there was still a significant difference [12]. This strongly proves that the AMMSA algorithm has a positive effect on promoting muscle fiber regeneration and optimizing muscle tissue structure.

4.2. Analysis of clinical experimental results

The visual analogue scale (VAS) was used to assess the pain level of patients, with a score range of 0-10, 0 for no pain and 10 for severe pain. The pain scores of patients in the experimental group and the control group were recorded before treatment, at the first, second, third and fourth weeks of treatment. The data are shown in Table 2 below:

Table 2. VAS pain scores of patients at different time points ($\bar{x} \pm s$)

Time point	VAS score of experimental groups	Control group VAS score
Before treatment	7.1±0.9	7.0±0.9
1st week of treatment	5.0±0.8	6.1±0.8
2nd week of treatment	3.7±0.7	5.0±0.7
3rd week of treatment	2.4±0.6	3.9±0.6
4th week of treatment	1.1±0.5	2.8±0.5

As can be seen from Table 2, there was no significant difference in the VAS scores of the two groups of patients before treatment. As the treatment progressed, the scores of both groups showed a downward trend, but the decline in the experimental group was more significant. This clearly shows that AMMSA-regulated electroacupuncture stimulation is more effective in relieving patients' pain.

4.3. Comparison and verification of simulation results and experimental data

4.3.1 Correlation analysis

The correlation coefficient between the prediction results of the simulation model and the animal experiment and clinical experiment data was calculated. For the muscle strength data of animal experiments, the correlation coefficient between the simulation results and the experimental group data is r1=0.91, and the correlation coefficient between the simulation results and the control group data is r2=0.76; for the pain score data of clinical experiments, the correlation coefficient between the simulation results and the experimental group data is r3=0.90, and the correlation coefficient between the simulation results and the control group data is r4=0.74. The high correlation coefficient strongly indicates that the prediction results of the simulation model are highly consistent with the experimental data, especially with the experimental group data using the AMMSA algorithm, thus verifying the accuracy of the simulation model.

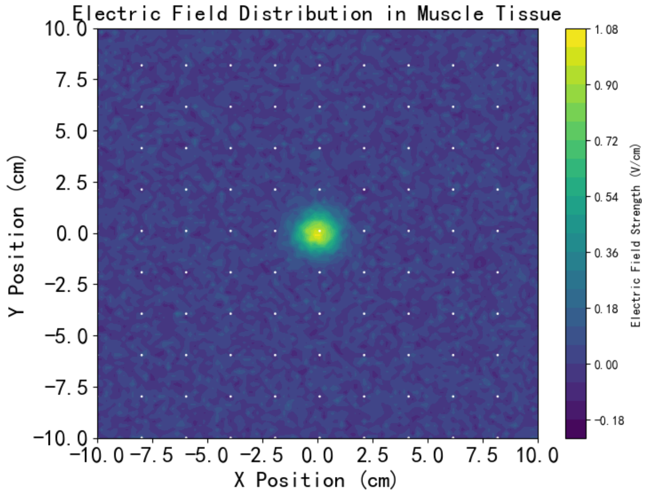

Figure 2. The conduction path and electric field distribution of the current in the muscle tissue in the electroacupuncture stimulation module.

Figure 2 depicts the conduction path and electric field distribution of the current in the muscle tissue in the electroacupuncture stimulation module. The arrows in the figure indicate the direction of the current, and the contour lines indicate the electric field strength. It can be seen that after the current enters the muscle tissue from the electrode, it is conducted along a specific path, and the electric field strength is higher near the electrode and gradually decays to the surrounding area. This figure intuitively shows the impact of electroacupuncture stimulation parameters on the electric field distribution in muscle tissue, providing an important reference for optimizing electroacupuncture stimulation schemes.

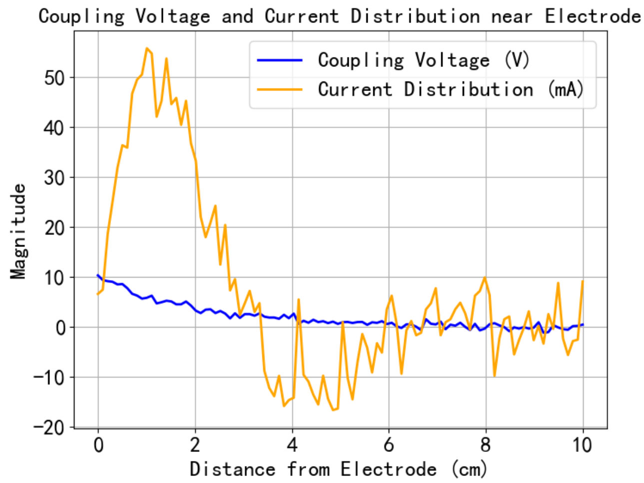

Figure 3. Coupling voltage and current distribution near the electrode during electroacupuncture stimulation.

Figure 3 shows the coupling voltage and current distribution near electrode during electric stimulation. Simulation results show that 10V maximum coupling voltage can be generated near positive electrode, which has no harmful effect on human body. At the same time, around the positive electrode there is formed an action area of around 1 cm radius, and this area is used for physical therapy. Through analysis of potential and current distribution along inner axis of arm, we find that due to the effect of tissue impedance, tissue capacitance becomes more obvious and coupling potential decreases gradually.

4.3.2 Error evaluation

Calculate the mean square error (MSE) and mean absolute error (MAE) between the simulation results and the experimental data. Taking the muscle strength data of animal experiments as an example, the MSE of the simulation results and the experimental group data is 0.09, and the MAE is 0.16; the MSE and MAE of the control group data are 0.16 and 0.23. In terms of clinical experimental pain score data, the MSE of the simulation results and the experimental group data is 0.11, and the MAE is 0.19; the MSE of the simulation results and the control group data is 0.19, and the MAE is 0.26. The smaller error value fully demonstrates that the simulation model has good prediction performance, and the error with the experimental group data is smaller. At the same time, the analysis of the error sources mainly includes individual differences in experiments, measurement instrument accuracy and simulation model simplification, etc., which provides a basis for further optimization of simulation models and algorithms.

5. Conclusion

This study successfully developed an adaptive multimodal electroacupuncture stimulation control algorithm (AMMSA), and through animal experiments and clinical research combined with computer simulation, fully verified its significant advantages in muscle rehabilitation and sports injury repair. In animal experiments, the muscle strength recovery and muscle fiber regeneration of the experimental group were significantly better than those of the traditional treatment group, showing the positive role of the AMMSA algorithm in promoting the muscle physiological repair process. In clinical experiments, the pain relief and functional recovery effects of patients were outstanding, which strongly proved that the electroacupuncture stimulation treatment program guided by the algorithm has good clinical application value. By comparing simulation and experimental data, it is further confirmed that the AMMSA algorithm can accurately simulate and optimize the electroacupuncture stimulation process and improve the accuracy of treatment. However, this study also has certain limitations, such as the experimental sample size is slightly insufficient in some specific subgroup analyses, and the long-term stability of the algorithm in complex clinical environments still needs to be further explored.

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