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Research on matrix decomposition-based optimization method for high-dimensional rehabilitation data during sports for disabled people

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ABSTRACT
Solving the health problems of key populations such as people with disabilities is an important way to realize universal health coverage and promote social equity. Sports as the main means of rehabilitation for disabled people at present, this study clarifies the concept of disabled people and sports rehabilitation, and uses empirical investigation to analyze the plight of cruel sports, laying a realistic and theoretical foundation for this paper based on high-dimensional rehabilitation data optimization. In the process of sports rehabilitation exercise for the disabled, it is generated through the modular control of multi-skeletal muscles by the central nervous system as well as the regulation of neural oscillations. And the surface EMG signal is the combined effect of superficial muscle EMG and electrical activity on the nerve trunk on the skin surface, which belongs to the high-dimensional data characteristics. For this reason, this paper constructs a rehabilitation exercise muscle synergy model using matrix decomposition for the rehabilitation of disabled people's sports. The data were refined in the time domain by adding time windows, and then the data were decomposed into targets based on the non-negative matrix decomposition method to extract the muscle synergy features in each time window, so as to analyze the muscle synergy differences in different exercise processes and different feature frequency bands, and to further obtain the muscle synergy law during exercise and the physiological change mechanism of the nervous system during exercise control. Finally, the experiments were carried out in both non-electrical stimulation and electrical stimulation modes, and the results showed that the number of muscle synergism in wrist flexion and extension was the same in both modes, which was 3. However, the number of synergistic pairs of muscles in the electrical stimulation mode was significantly increased. It also proves the effectiveness of the method of this paper on the analysis of muscle synergy of multi-channel surface EMG signals, which provides a new method for exploring the muscle synergy characteristics and the control mechanism of rehabilitative movement in the process of disabled people's sports.

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1. Introduction

Sports is a very important activity for physically and mentally healthy people, which can not only enhance physical fitness and coordination ability, but also cultivate the spirit of teamwork and sense of competition. However, for disabled people, sports are even a beneficial way of rehabilitation, such as wheelchair basketball, deaf soccer, wheelchair fencing, and prosthetic long jump [1-4].

First of all, by participating in sports activities, disabled people can have proper exercise training to increase joint flexibility and improve muscle strength and endurance [5-8]. For example, frequent pushing exercises in wheelchair basketball games can improve the strength and coordination of the upper limbs by exercising the arm and back muscles. Similarly, water sports such as swimming also have good effects on the physical rehabilitation of the disabled, as the buoyancy of water can reduce the pressure on the body, thus helping to improve the flexibility of joints and muscle coordination. Secondly, physical activities can also promote the function of circulatory system, respiratory system and other systems of the disabled, and improve the overall condition of the body [9-11]. In addition, physical activities have a positive contribution to the psychological rehabilitation of disabled people. Physical disability may bring psychological distress and pressure to the disabled, while participation in sports activities can improve their self-esteem and self-confidence and ease the psychological burden. Sports activities can help disabled people establish a positive mindset, develop a sense of teamwork and competition, and enhance their ability to face difficulties and setbacks [12-15]. Furthermore, sports activities can also deal with their own disability shame, promote the integration of people with disabilities into society, expand their social circle, improve their social skills and interpersonal relationships, and promote social inclusion [16-19]. Taken together, sports provide a platform for people with disabilities to display their talents and show their individuality, and is one of the most important means to help people with disabilities rehabilitate and integrate into society at both the physical and psychological levels [20].

Rehabilitation therapy during physical activity for people with disabilities is a comprehensive process, and analyzing the rehabilitation data it generates is beneficial for medical practitioners to plan and adjust rehabilitation programs in a timely manner. The patient's genetic data and rehabilitation data such as rehabilitation programs and rehabilitation medical imaging examinations increase day by day, constituting high-dimensional rehabilitation data. However, as the dimensionality of the data increases, the sparsity of the data samples also increases, and the distance measurement between the data becomes difficult, which makes it infeasible to use traditional data analysis methods to accurately characterize the data [21-23]. Meanwhile, with the increase of dimensionality, the correlation between the data decreases, which leads to the generation of various biases and errors, affecting the accuracy and reliability of data analysis [24]. Therefore, optimizing high-dimensional rehabilitation data has important practical significance for the rehabilitation training of disabled people.

This study firstly clarifies the concepts of disabled people and sports rehabilitation, and carries out an empirical investigation on the issue of sports rehabilitation for disabled people, in-depth research on the status quo and dilemma of sports rehabilitation for disabled people, in order to lay a realistic and theoretical foundation for the research of this paper. The purpose of sports rehabilitation for the disabled is to restore and improve the patients' physical functions and realize their normal motor behaviors. And all human motor behaviors are inseparable from the control mechanism of the central nervous system. Muscle synergy is a modularization of motor control, which simplifies the hierarchical control of the motor system, thus revealing the intrinsic functional pattern of the nervous system.

Therefore, this project focuses on the study of muscle synergy in the process of rehabilitation exercise, selects the high-dimensional data surface EMG signals as the muscle synergy research means according to the generation mechanism and the use of EMG signals, and constructs the muscle synergy model of rehabilitation exercise based on matrix decomposition. Finally, the effect of this paper's method model is verified by the experimental results in different modes, which provides an effective method for the research of sports for the disabled.

2. Analysis of the real-life dilemma of sports and rehabilitation for persons with disabilities

Sports rehabilitation for persons with disabilities is an important part of the "Healthy China" strategy, and an important initiative for practicing people-centered development thinking. With the continuous development of society and the increasing population size, the number of disabled people has reached 85 million, and the demand for the protection of the rights and interests of disabled people has gradually increased. This paper firstly clarifies the concept of disabled people and sports rehabilitation, and analyzes the current situation of disabled people's sports and rehabilitation, which lays the foundation for the in-depth study of disabled people's sports and high-dimensional data optimization methods in this paper.

2.1. Persons with disabilities

The definitions of "disability" and "persons with disabilities" vary to varying degrees, depending on the time period, geographic location and cultural background; in 1982, the World Programme of Action concerning Disabled Persons stated that "disability is a condition of the body that makes it impossible to carry out normal social activities"; in 1997, the World Health Organization categorized three types of disability that affect individuals differently: In 1982, the World Programme of Action concerning Disabled Persons mentioned that: "Disability is the result of an impairment of a particular aspect of the body that makes it impossible to carry out normal social activities." In 1997, the World Health Organization (WHO) classified the different degrees of disability affecting an individual into three categories: firstly, the functional form of disability, which refers to the damage brought by external factors or the damage brought by disease to the structure of the self. The first is functional-physical disability, which refers to impairments caused by external factors or damage to one's own structure due to disease. The second is functional disability, which means that the organism itself has normal human abilities, but due to various factors, this ability is reduced or absent. Thirdly, it is an obstacle to social life, in which persons with disabilities lose the ability to participate in normal social activities due to morphological defects and functional obstacles, such as persons with leg disabilities who use a wheelchair to access steps via ramps. According to the standards of the World Health Organization (WHO) and the International Standards Organization (ISO), the term "disabled person" is defined as follows. It is a human being who, due to congenital or acquired factors, has physical, mental, and spiritual conditions that make it difficult for him or her to perform normal activities in a normal area in a normal manner. According to the criteria for disability, persons with disabilities are broadly categorized into physical disabilities, visual disabilities, hearing disabilities, speech disabilities, intellectual disabilities, mental disabilities, multiple disabilities, and other disabilities (cardiopulmonary disabilities, more severe heart diseases, emphysema, etc.).

2.2. Sports rehabilitation

Sports rehabilitation is based on the characteristics of injuries and diseases, and adopts the means of sports or body function exercises to achieve the purpose of prevention, treatment and rehabilitation of injuries and diseases. Sports rehabilitation is different from general sports, sports is a healthy person in order to enhance physical fitness and improve motor skills engaged in physical exercise, sports rehabilitation must be based on the characteristics of the disease and the patient's physical condition, the choice of the appropriate exercise methods, the arrangement of the appropriate amount of exercise to treat the disease and trauma. In various diseases after the acute stage into the recovery period, sports rehabilitation is to shorten the recovery period, as soon as possible to restore the normal function of the body's proven methods and means. As early as in primitive society, people in the process of fighting with nature, has gradually accumulated the experience of using sports means of disease prevention and treatment, the rapid development of modern sports, sports rehabilitation is not less than hundreds of kinds, but according to its purpose and task, can be divided into fitness therapy, fitness therapy, recreational therapy and athletic therapy. Among them, the purpose of fitness-based therapies is for fitness, rehabilitation and treatment of diseases.

2.3. Difficulties in the Rehabilitation of Sports and Physical Education for Persons with Disabilities

This study reviewed relevant books, magazines, journals, etc. in the fields of rehabilitation of the disabled, rehabilitation sports, and integration of sports and medicine in a number of university library and archives, sports academy libraries, and provincial libraries. And network search in China Knowledge Network, Baidu Scholar, Wanfang Database, Google Scholar and other databases, and then targeted and purposeful screening, summarizing and organizing and synthesizing the relevant literature, to provide theoretical support and reference for this paper's analysis of the dilemma of the rehabilitation of disabled people's sports. At the same time, in order to more deeply understand the current situation of rehabilitation sports for people with disabilities and the development path of the relevant issues of people with disabilities conducted a practical investigation and research.

2.3.1. Questionnaire design. In order to make the questionnaire design scientific and reasonable, the researcher of this paper carefully read and referred to the research results of previous related researchers, combined with visits to the teachers and students of the physical education colleges of several key universities in the mountains and the rehabilitation staff of the rehabilitation centers for the disabled, to get a preliminary understanding of the most important concerns of the disabled groups about rehabilitation sports, and designed the first draft of the questionnaire accordingly. Afterwards, we invited experts and teachers in related fields, as well as master and doctoral students, to further review the draft questionnaire and make valuable modifications.

2.3.2. Questionnaire reliability tests. In order to ensure the validity of the survey, the validity of the questionnaire needs to be tested before distributing the questionnaire, and the researcher of this paper invited 10 experts in the field of rehabilitation sports for the disabled to evaluate and score the questionnaire in terms of the structure of the questionnaire, the reasonableness of the content, and the comprehensiveness of the questionnaire. The validity of the questionnaire is shown in Table 1, and it can be seen that the questionnaire design of this paper has an average score of 2.13, 2.00 and 2.00 on the structure of the questionnaire, the reasonableness of the content and the comprehensiveness, and the overall average score is 2.04, which is between general and more reasonable, indicating that it can be used as a questionnaire for the present study.

Table 1. Questionnaire validity

Evaluation project	Very reasonable (1)	Reasonable (2)	General (3)	Unreasonable (4)	Very unreasonable (5)	Integrated average score
Questionnaire content	5	3	2	0	0	2.13
Questionnaire structure	6	3	0	1	0	2.00
Overall questionnaire	5	4	1	0	0	2.00
Mean	5.3	3.3	1	0.3	0	2.04

In addition, this study adopted the retesting method to test the reliability of the questionnaire, and seven days after the first questionnaire was collected, a random selection was made among the above valid respondents, and then the KAPPA consistency coefficient analysis was carried out. The results show that the KAPPA coefficient of the two questionnaires is 0.88, which meets the reliability requirements of the questionnaire design.

2.3.3. Results of the survey on sports rehabilitation for persons with disabilities. In this study, a total of 100 disabled people from special education schools and rehabilitation centers for the disabled were selected as survey respondents, and the ratio of male and female students was about 5:4. The questionnaire was quantified using a score of 1~5, and the higher the score, the more in line with the actual situation.

The results of the analysis of the motivation of sports rehabilitation of the disabled are shown in Table 2. The motivation of sports rehabilitation of the disabled is mainly to enhance physical fitness, regulate emotions, show value, enhance confidence and restore physical functions. Among them, the average scores for enhancing physical fitness and restoring physical functions are relatively higher, at 4.23 and 4.61 respectively, which shows that the disabled people who participate in sports attach more importance to improving their physical fitness and restoring physical functions.

Table 2. Analysis of motivation analysis of sports rehabilitation of disabled persons

Motive dimension	N	Maximum	Minimum	Mean
Enhanced constitution	100	5	3	4.23
Regulating emotion	100	5	3	3.15
Display value	100	5	2	2.95
Boost confidence	100	5	2	2.13
Restore body function	100	5	3	4.61

The results of the survey on people with disabilities' non-participation in sports rehabilitation are shown in Table 3. The main reasons for people with disabilities' non-participation in sports rehabilitation include physical constraints, lack of venues and facilities, lack of suitable sports programs, not wanting to play sports, lack of professional guidance, and lack of technical support. As can be seen from the table, the average score of physical constraints is the highest at 4.12 points, and the average score of not wanting to exercise is only 2.02 points. It shows that most of the disabled people do not participate in sports rehabilitation mainly because of the physical constraints of physical disability, and their willingness to participate in sports rehabilitation for the disabled is high. In addition to their own physical limitations, the external environment and facilities are also important influencing factors. The lack of venue facilities, suitable sports programs, professional guidance and technical support are also important reasons why people with disabilities do not participate in sports and physical rehabilitation, with the average scores of each indicator being above 3 points.

Table 3. Disabled persons are not involved in the survey results of sports rehabilitation

Reason dimension	N	Maximum	Minimum	Mean
Physical restriction	100	5	3	4.12
Lack of facilities	100	5	2	3.98
No fit sports	100	5	3	3.56
Don't exercise	100	5	1	2.02
Lack of professional guidance	100	5	2	3.05
Lack of technical support	100	5	3	3.67

The results of the survey on the expectations of persons with disabilities for sports rehabilitation are shown in Table 4, and the expectations of persons with disabilities for sports rehabilitation include the help provided by rehabilitation centers, the improvement of medical protection, the construction of rehabilitation centers, the development of sports activities, and the construction of additional infrastructures for persons with disabilities, and so on. As can be seen from the table, the scores of all dimensions of the expectations of the disabled for sports rehabilitation are above 4, indicating that the disabled have high expectations for all dimensions. Among them, the issue of medical protection (4.62) is of the greatest concern, probably due to the fact that their families are not rich because of their own disabilities, and therefore many people with disabilities are more eager to solve the problem of medical treatment received for their disabilities.

Table 4. The disabled are expected to investigate the results of the sports recovery

Expectation dimension	N	Maximum	Minimum	Mean
Help from rehabilitation centers	100	5	2	4.12
Increased health care	100	5	3	4.62
Rehabilitation center	100	5	3	4.05
The development of sports activities	100	5	2	4.06
Infrastructure for building disabled persons	100	5	2	4.41

2.3.4. Summary of the dilemma of sports rehabilitation for the disabled. According to the results of the survey on the actual situation of the disabled in this paper and combined with the study of relevant information, the sports rehabilitation of the disabled is summarized as follows:

1) Low awareness of sports rehabilitation and lack of medical protection. Although at present, with the development of society, people have begun to have the awareness of sports, many people are not clear about what kind of sports are needed to maintain their physical and mental health, and there is still a lack of scientific understanding of the relationship between sports and health, especially for people with disabilities. In addition, because of the lack of understanding and ability of medical practitioners to provide exercise guidance to patients, many medical practitioners can only give rehabilitation advice to people with disabilities in terms of medical treatment, but they are not able to help people with disabilities to recover their functions through physical exercise. Moreover, the medical insurance for the disabled is not strong enough, and most of them can only guarantee the basic survival of the disabled.

2) Shortage of Sports Rehabilitation Talents in Rehabilitation Centers for the Disabled. There is a relative lack of training for complex talents in sports and physical health. Each rehabilitation center for the disabled, only for medical colleges and universities to provide internships and employment positions, for sports rehabilitation professional cooperation is less, not a reasonable use of the city's resources.

3) Insufficient knowledge of patients about sports rehabilitation and insufficient publicity of sports rehabilitation. At present, people still agree with the traditional rehabilitation methods and treatments, and the awareness of sports rehabilitation is weak. Most of the patients still face their conditions with the purpose of treatment, and they don't want to spend time and energy on rehabilitation training, so there is still a lot of room for improvement in the development of sports rehabilitation.

4) Serious separation of medical treatment and sports, each in its own way. The integration of sports and medicine is an innovative practice for the common development of sports and medical care. From the point of view of the means of both for health, sports can serve medicine, and medicine can guide sports and provide non-pharmaceutical interventions, giving full play to the exercise function of sports and the scientific intervention function of medicine. Therefore, it is imperative to set up an inter-administrative cooperation organization to oversee the integration and symbiosis of the two sectors.

3. Optimization of high-dimensional rehabilitation data based on matrix decomposition

3.1. Rehabilitation exercise muscle synergy based on matrix decomposition

Based on the above investigation and analysis related to sports rehabilitation of disabled people, it provides an effective tool to improve the efficiency of sports rehabilitation of disabled people and provide an effective tool for the plight of sports rehabilitation of disabled people. Surface EMG signal is the combined effect of superficial muscle EMG and electrical activity on the nerve trunk on the surface of the skin, which can reflect the neural activity of the muscle to a certain extent, and has a high-dimensional character. Therefore the study of surface EMG signals is extremely helpful in exploring CNS coordination mechanisms.

The execution of rehabilitation sports for the disabled requires coordinated control of the activation of multiple skeletal muscles, i.e., muscle synergy. This action can reflect the inter-coordination between multiple muscles in the process of neural control of movement, and muscle activation also has obvious frequency band characteristics, and different frequency band information can reflect the motor nerve control process. Although the traditional non-negative matrix decomposition method has been widely used in the study of synergistic properties, the method only focuses on the synergistic analysis of a single time scale, and has some limitations in exploring the frequency characteristics of muscle synergistic structures during dynamic changes. Therefore, this paper proposes a non-negative matrix factorization method (WPT-NMF) to analyze muscle activation patterns in the time-frequency domain. The method further describes the number of decomposition modules of multichannel EMG signals in different frequency bands and the variation rule of the synergy matrix over time by decomposing the signals in the time-frequency domain, which provides a new method to explore the muscle synergy characteristics and motor control mechanisms. The muscle time-frequency synergy analysis model is shown in Fig. 1, and in order to characterize the time-frequency synergy of the signal, a wavelet packet-nonnegative matrix decomposition model is constructed in this chapter. Firstly, based on the feature that the WPT decomposition method can decompose both high frequency and low frequency the time domain EMG signals in a specific motion mode are transformed into the time-frequency domain to obtain the multidimensional information of the signals. Then the data is refined in the time domain by adding time windows. Finally, based on the NMF method, the data can be decomposed into the target base without any negative influence of the features from different frequency bands to extract the muscle synergy features in each time window, in order to analyze the muscle synergy differences in different movement processes and different feature frequency bands, and further to obtain the muscle synergy law during the movement process and the physiological change mechanism of the nervous system during the movement control process.

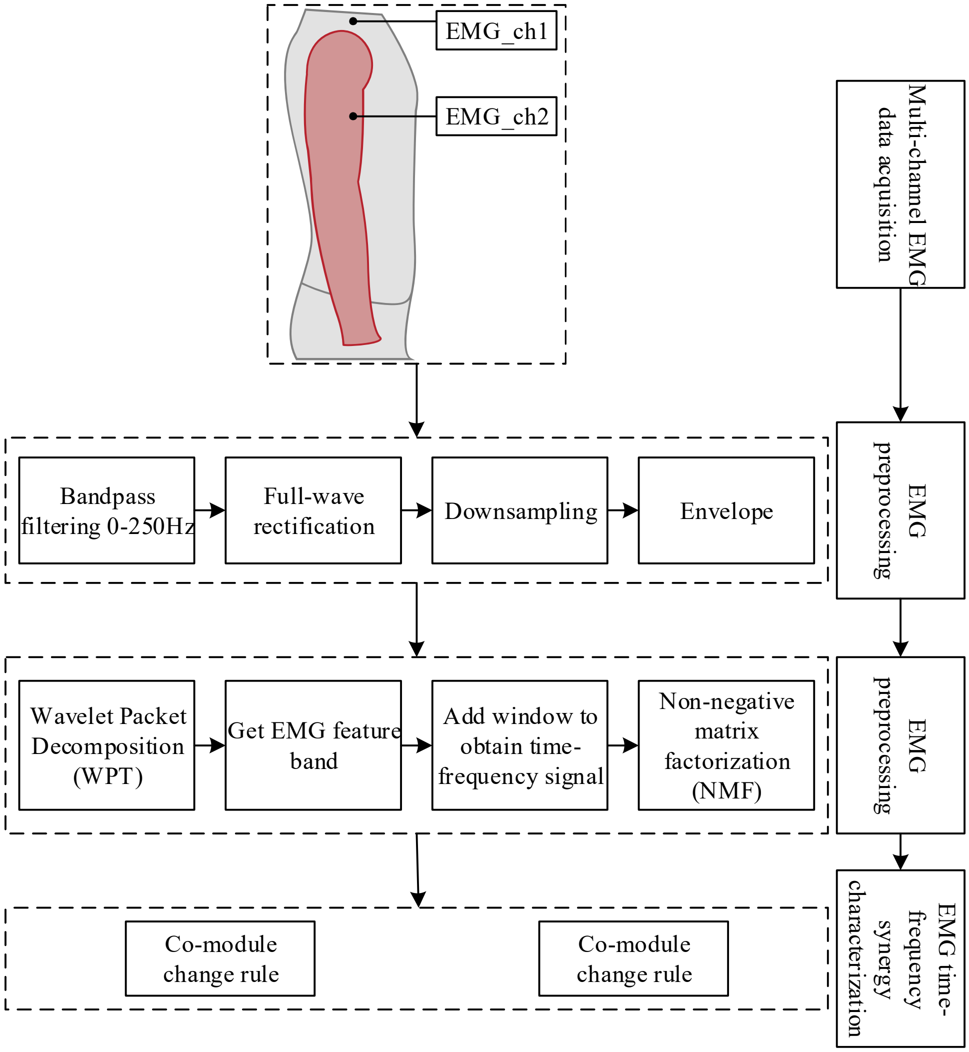

Fig. 1. Based on WPT-NMF's muscle time-frequency collaborative analysis framework

3.2. *Time-frequency decomposition of EMG signal based on wavelet packet decomposition*

Wavelet packets can decompose nonsmooth signals in time and frequency domains in a better way than Fourier transform, especially due to their high resolution at high and low frequencies and are widely used in time-frequency analysis of biomedical signals. Therefore, in this paper, WPT is applied to extract the feature information of different dimensions of time domain EMG signals. The idea is as follows: define the time-domain EMG signal $X(t)$, apply wavelet packet to decompose it, when this time-domain EMG signal is decomposed into N layers, the signal in the $\left(0,2^{-1}fs\right)$ frequency band will be decomposed into 2^N subspaces, and each space corresponds to the frequency bands $\left((n-1)2^{j-1}fs, n2^{j-1}fs\right)$, $n=1,2,\cdots,2^N$, $j=-N$, where n represents the number of nodes, the sub-signal in the layer $N-th$ of the $n-th$ subspace can be obtained by the following equation:

$$X_N^n(t)=\sum_k XD_k^{N/n}\psi_{n,k}(t), k\in Z \tag{1}$$

where $\psi_{nk}(t)$ is the wavelet function and $XD_k^{N,n}$ is the wavelet packet coefficients of the EMG signal matrix in $n-th$ subspace $N-th$ layers, representing the data information in a specific frequency band.

3.3. Time-frequency coanalysis of muscles based on nonnegative matrix decomposition

Based on the wavelet packet method, the time domain EMG signals are transformed into the time-frequency domain, and then the EMG signals $X_N^n(t)$ from different frequency bands are divided into L equal-length data segments through the time window $w(t)$ and the width of the window function $w(t)$ is equal to the number of samples per second, and then the signals from the different muscles in the same time window and the same frequency bands are combined to form a matrix X_{ml}, and finally, the multichannel EMG signals X_{ml} are decomposed into two matrices, W and C. The process can be expressed as the following equation:

$$X_{ml} \approx (WC)_{ml} = \sum_{i=1}^{k} W_{mi} C_{il} = X'_{ml} \tag{2}$$

where X_{mi} represents the m channel EMG signal matrix, l is the number of sampling points, k represents the number of synergistic modules, and W is the synergistic variable matrix, which can reflect the relative activation weights of each muscle in the $i-th$ muscle synergism, which in this paper is normalized to a value that varies over a $[0-1]$ range. These muscles are considered synergistic when their weight values are higher than 0.5, C is the time-varying coefficient, which can represent how the $i-th$ synergy matrix is modulated over time and reflects the contribution of each muscle synergy to the movement, and X_{mt} is the reconstructed EMG signal.

4. Muscle synergy experiments for basic nonnegative matrix decompositions

In this chapter, the experimental paradigms of wrist flexion and wrist extension movements under non-electrical stimulation and electrical stimulation were firstly established, and the data related to the surface EMG signals were simultaneously collected and pre-processed respectively, while the data were inputted into the non-negative matrix decomposition model for muscle synergy analysis, and then explored the muscle synergistic effects under the two experimental paradigms.

4.1. Analysis of muscle synergy under non-electrical stimulation

The study took the rehabilitation of the hand as an example, and 10 disabled subjects (5 males and 5 females, and all right-handed, aged about 22±5 years) were selected according to the requirements of the experiment. The experimental trials were a set of 10 trials, each with a duration of 11 s. A 60 s rest period was provided at the end of each trial to relieve fatigue. The experimental components of a single trial were mainly relaxation, translation, wrist flexion, and wrist extension.

The main muscle groups for wrist movement were biceps brachii (BB), palmaris longus (PL), brachioradialis (B), flexor carpi radialis (FCR), superficial flexor digitorum superficialis (FDS), extensor carpi radialis (ECR), extensor carpi ulnaris (ECU), and extensor digitorum (ED). These 8 muscles were used as the main acquisition channels for this experiment. The experimental data acquisition equipment was chosen as the TrignoTM Wireless EMG Wireless Transmission Synchronized Acquisition System from Delsys through which the data were recorded. Since the sEMG signal is a non-smooth random signal, it is very easy to be interfered by the external environment and the acquisition equipment, and at the same time, in order to get a higher quality signal for the subsequent analysis, this paper inputs the original sEMG signal acquired by the acquisition equipment into the program written in MATLAB, and pre-processes the original EMG data.

Using the non-negative matrix decomposition matrix constructed in this paper, the preprocessed wrist flexion and wrist extension maintenance phase portions of the acquired surface EMG signals were extracted and input into the non-negative matrix decomposition model. Before inputting the preprocessed wrist flexion and wrist extension surface EMG signals, the number of muscle synergy modules required for muscle synergy analysis was first determined. In this study, the minimum explained variance (VAF) was used for the determination of the number of muscle synergistic modules, and to accommodate the analysis of muscle synergy under wrist flexion and wrist extension maneuvers in this study, the VAF threshold method was used as the optimal research method. In this paper it is considered when the VAF value is greater than 90% and when the number of synergistic modules is increased and the increase in VAF is less than 2%. Its module value is chosen as the least effective value. The relationship between the VAF value and the number of synergistic modules under wrist flexion and wrist extension maneuvers is shown in Figure 2. From the figure, it can be seen that when the number of muscle synergistic modules was gradually increased, the VAF value also increased. When the number of synergy modules is 3, the VAF value satisfies greater than 90% and the number of synergy modules increases by 1, the increase of VAF value is less than 2%, at this time, the number of synergy matrices is determined to be 3 as the minimum number of synergy, which is used as the optimal number of synergy for the subsequent non-negative matrix decomposition.

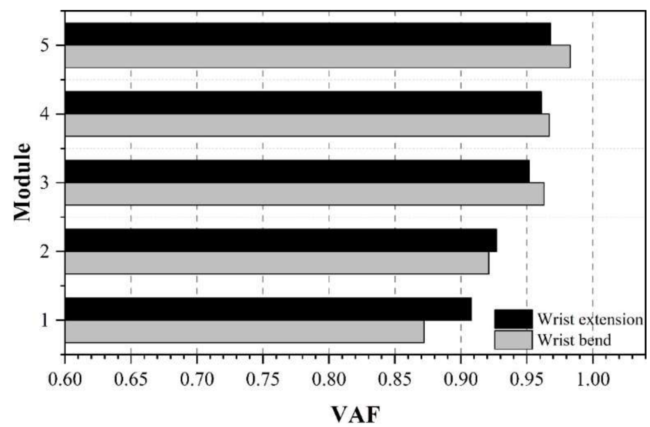

Fig. 2. The relationship between the VAF value and the number of collaborative modules

The experiment first acquired preprocessed 8-channel surface EMG signals. Then, the number of muscle synergy modules was determined to be 3. Next, spatiotemporal muscle synergy was extracted from these 8 muscles to discover the changes in synergy during wrist movements, and the average signals of 10 subjects with different movements were analyzed by NMF. The results of muscle synergy based on matrix decomposition are shown in Figure 3. As can be seen in the figure, the central nervous system activates these synergistic muscle pairs to accomplish the maintenance movement of the phase. From the experimental paradigm, it can be seen that each trial is 10 s. Under the wrist flexion and wrist extension movements, 3-5 s is the wrist flexion maintenance time, and 7-9 s is the wrist extension maintenance time, and there are three pairs of synergistic muscle dominant muscle groups (PL-FDS, PL-BB, and FDS-BB) in the muscle synergy module during the wrist flexion maintenance time. During the wrist extension maintenance time, there were 3 pairs of synergistic muscle dominant muscle groups (ED-ECU, ED-B, ECU-B) in the muscle synergy module.

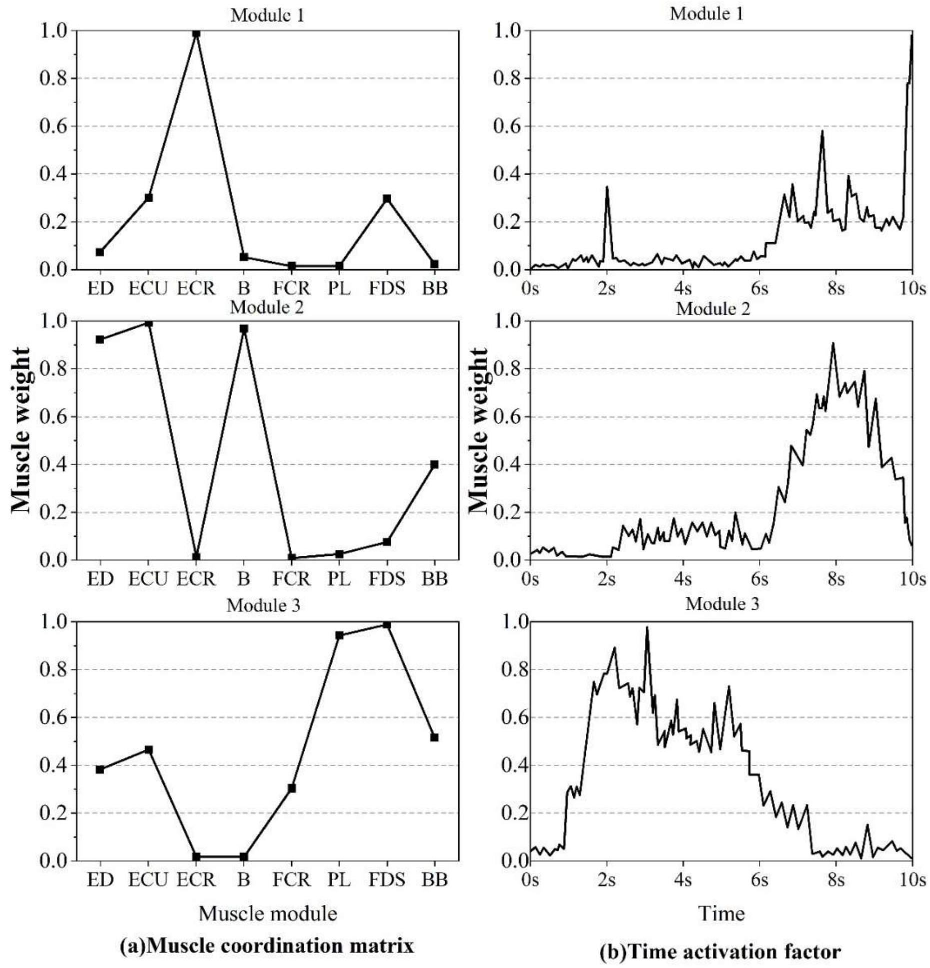

Fig. 3. Based on matrix decomposition

4.2. *Muscle synergy analysis under electrical stimulation*

Functional electrical stimulation is an important means of rehabilitation exercise training, this section intends to explore the basis of muscle synergy under wrist flexion and extension movements, applying functional electrical stimulation, utilizing the stimulation current to act on the corresponding muscle channels controlling the wrist flexion and extension movements, activating the relevant nerves of the channels to produce muscle contraction movements, so as to complete the wrist flexion and extension movements, so the experimental paradigm was designed for the functional rehabilitation of electrical stimulation and the experimental data were collected. Therefore, we designed an experimental paradigm for functional rehabilitation with electrical stimulation and collected the experimental data, and at the same time, utilized NMF as the muscle synergy analysis algorithm to extract the muscle synergy matrix and analyze the muscle synergy effect of wrist flexion and wrist extension movements under electrical stimulation. Muscle synergy analysis of wrist flexion and extension movements under electrical stimulation was performed on eight upper limb muscles. Similarly, the number of muscle synergy modules for wrist flexion and extension movements under electrical stimulation needs to be determined by the VAF threshold method before input, and the relationship between the VAF value and the number of synergy modules for wrist flexion and extension movements under electrical stimulation is shown in Figure 4. From the figure, it can be seen that the optimal number of synergistic modules for VAF is 3, and it satisfies the conditions required by VAF, so it is determined that VAF is equal to 3 as the optimal number of modules for the synergistic action analysis later.

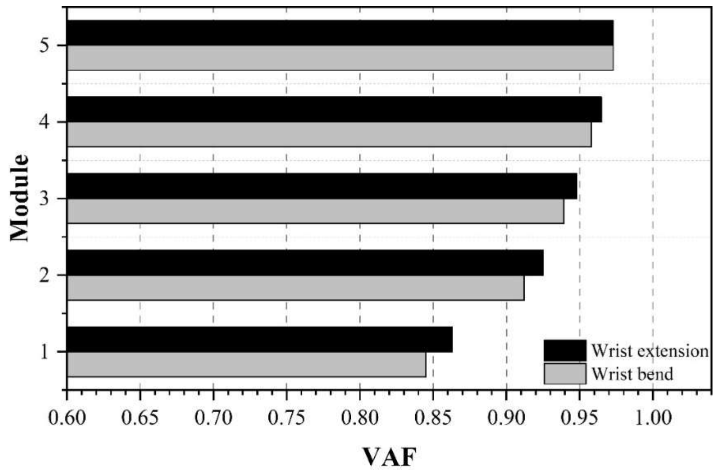

Fig. 4. The relationship between the VAF value and the number of collaborative modules

The analysis of muscle synergy based on matrix decomposition under electrical stimulation is shown in Fig. 5, which shows that the wrist flexion maintenance time is 3~5 s, and the wrist extension maintenance time is 7~9 s. During the wrist flexion maintenance process of electrical stimulation, the muscle synergy module exists 6 pairs of synergistic muscles (FCR-PL, FCR-FDS, FCR-ECU, PL-ECU, PL-FDS, and FDS-ECU) as the dominant muscle groups. The FDS-PL served as the synergistic muscle group in the muscle synergy module. Similarly in the wrist extension maintenance phase of electrical stimulation, the six pairs of synergistic muscles in the muscle synergy module were ED-ECU, ED-ECR, ED-B, ECU-ECR, ECU-B and ECR-B.

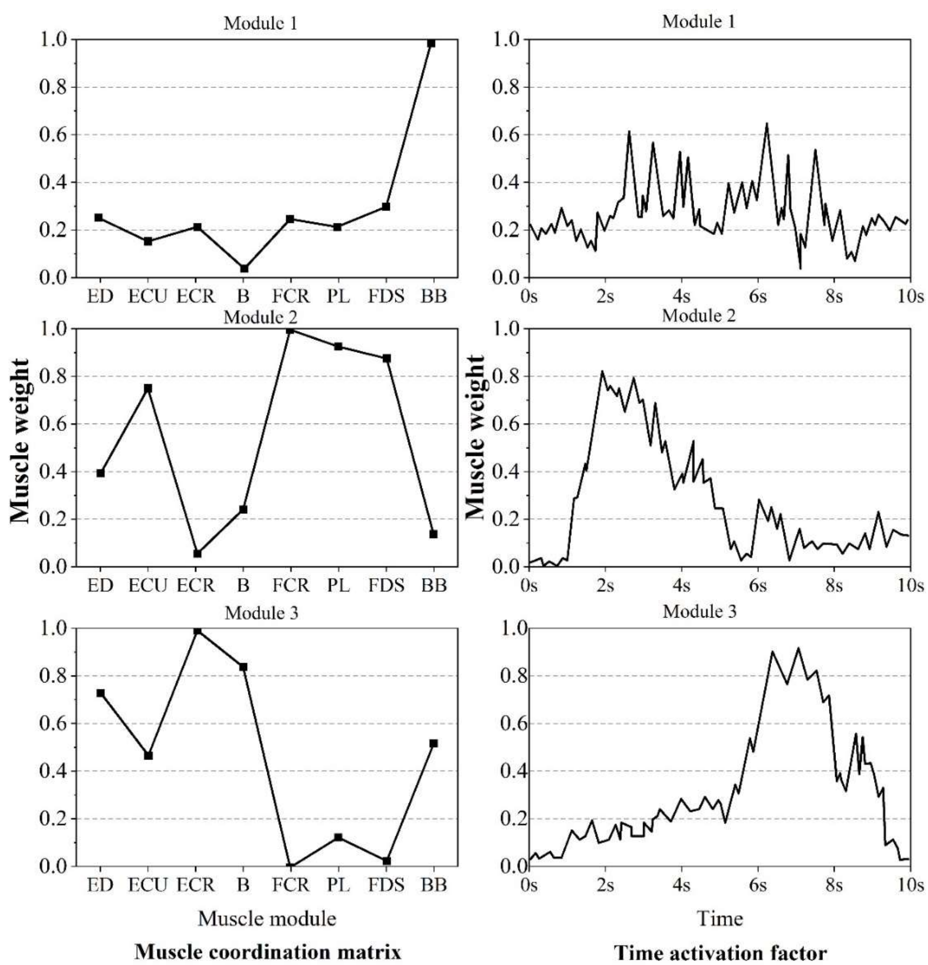

Fig. 5. The muscles of the electric stimulus are analyzed

Based on the experimental results in both non-electrical and electrical stimulation modes, it can be found that the number of muscle synergies involved in wrist flexion and extension is the same in both electrical stimulation modes compared to non-electrical stimulation modes, which is 3. However, the number of synergistic muscle pairs involved in the action is significantly increased in electrical stimulation modes, and muscle synergies are significantly stronger than those in non-electrical stimulation modes in terms of space. The experimental results show the effectiveness of this paper's method for muscle synergy analysis of multichannel surface EMG signals under non-electrical and electrical stimulation.

5. Conclusion

This study is oriented to the disabled sports to carry out practical investigation and research on its current situation and dilemma, and for the generation mechanism of electromyographic signals in the disabled sports process, the surface electromyographic signals are selected as a means of muscle synergy research, and the muscle synergy model based on matrix decomposition is constructed. The main results of this study are as follows:

1) According to the results of the survey on sports for the disabled, it was found that among the motives of sports rehabilitation for the disabled, the average scores of physical enhancement and restoration of physical function were relatively higher, 4.23 and 4.61 respectively, and the disabled group attached more importance to the enhancement of their own health and the restoration of physical function. The average score for physical constraints was the highest at 4.12, and the average score for not wanting to exercise was only 2.02, indicating that the reason for not participating in sports rehabilitation was mainly due to the constraints of physical disability, and the willingness to rehabilitate the disabled in sports was high. The scores of all dimensions of the expectation of disabled people for sports and physical rehabilitation are above 4 points, indicating that disabled people have high expectation for all dimensions. The construction of sports rehabilitation for people with disabilities is not comprehensive, and the construction of their facilities and the protection of their systems still need to be further improved.

2) In this paper, a muscle synergy model based on matrix decomposition is constructed for the surface electromyographic signals during sports for the disabled. Through experiments, it was found that under non-electrical stimulation, 3 pairs of synergistic muscle dominant muscle groups existed in both the wrist flexion and wrist extension maintenance time course of the muscle synergy module. In contrast, 6 pairs of synergistic muscle dominant muscle groups existed in both electrical stimulation modes. By comparison, it can be seen that the number of muscle synergies in both modes of wrist flexion and wrist extension was 3. There was a significant increase in the number of synergistic muscle pairs in the electrical stimulation mode, and its spatial muscle synergies were significantly stronger than those in the non-electrical stimulation mode. The overall experimental results verified the practical effect of the method of this paper on the muscle synergy analysis of surface EMG signals during sports for the disabled.

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