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Latest Developments in Physical Fatigue Evaluation Methods in Patients with Stroke

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【**Abstract**】 Physical fatigue is common in stroke patients，which adversely affects the functional recovery and long term quality of life. Currently available studies about post-stroke fatigue，especially physical fatigue，are limited，and show a large degree of heterogeneity，with controversial results. We reviewed the latest developments in physical fatigue evaluation methods in stroke patients，with a view to assisting clinical selection of an appropriate physical fatigue evaluation method for such patients.

【**Key words**】 Fatigue；Stroke；Physical functional performance；Physical fatigue；Evaluation studies；Review

Key points of this article: With the deepening of the research on post-stroke fatigue (PSF), researchers are gradually more deeply aware of the importance of fatigue in the rehabilitation of stroke patients, but there is still a lack of unified PSF evaluation criteria, especially in physical fatigue. This article summarizes the evaluation methods of PSF and analyzes the different dimensions of PSF, so as to reflect the evaluation of physical fatigue of stroke patients. At the same time, it also summarizes the relevant evaluation methods based on physiological and biochemical indexes, so as to provide reference for clinical workers to better evaluate the physical fatigue of stroke patients.

Stroke is a group of organic cerebrovascular diseases, which are characterized by sudden onset, rapid onset of localized or diffuse brain damage, and common features of cerebrovascular diseases[1]. It has the characteristics of high incidence rate and high mortality rate, which seriously affects the quality of life of patients[2]. Post-stroke fatigue (PSF) is one of the common complications of stroke. It refers to the persistent pathological fatigue that can not be relieved after rest in stroke patients[3], in which physical fatigue plays a leading role. PSF patients are mainly characterized by lack of physical strength, general fatigue or inability to maintain activities of daily living, and obvious fatigue, decreased energy or need to increase rest time every day or often in the past 1 month and 2 weeks. Research shows that PSF directly affects the rehabilitation process of stroke patients and seriously affects their quality of life[4-5].

The intervention of PSF is based on evaluation, but there is still a lack of unified evaluation criteria. Clinically, it mostly depends on the evaluator's experience and lacks objective basis. However, the relevant evidence-based medicine research is still controversial, and mainly focuses on the reliability and validity of the scale. In recent years, there are a few research reports on PSF non scale evaluation methods, but no consensus has been reached. Therefore, scale evaluation method is still the most important clinical PSF evaluation method at this stage. This article mainly reviews the evaluation methods of physical fatigue in stroke patients, in order to provide reference for the rational selection of effective methods to evaluate physical fatigue in stroke patients.

1 Scale evaluation methods

Although the scale evaluation method is the most important clinical PSF evaluation method at this stage, there

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is no special PSF evaluation scale, so the scale for evaluating the fatigue status of patients with nervous system diseases is often used to evaluate PSF, involving single-dimensional scale and multi-dimensional scale, including Fatigue Severity Scale (FSS), Check List Individual Strength (CIS) and Fatigue Impact Scale (FIS) are three PSF evaluation scales used frequently in clinic.

FSS was developed by Krupp et al[6] in 1989. It is a single-dimensional scale, including 7 items. The main evaluation contents are the consequences of fatigue (decline of physical function, work and activity ability). It has high internal consistency and coexistence validity in patients with systemic lupus erythematosus and multiple sclerosis. It is the most commonly used scale to evaluate fatigue in clinic. The FSS evaluation content is simple and easy to fill in. The evaluation process takes only a few minutes and is easy for patients to accept. It is suitable for evaluating the fatigue status of stroke patients, but it can not evaluate the cognitive function and social function realization ability of patients[7].

CIS was developed by vercoulen et al[8] in 1994. It is a multi-dimensional scale, including 4 dimensions and 20 items. The main evaluation contents include subjective fatigue (8 items), attention (5 items), motivation (4 items) and physical strength (3 items). It has high internal consistency, half reliability and distinguishing validity and responsiveness is a reliable fatigue evaluation scale. Studies have shown that CIS can better evaluate the impact of fatigue on patients' cognitive function compared with FSS[7], which is suitable for evaluating the fatigue status of patients with cerebral infarction in China[9], but it is not sensitive to the change of patients' response ability[10].

FIS was developed by Fisk et al[11] in 1994. It is a multi-dimensional scale, including 3 dimensions and 40 items. The main evaluation contents include cognitive function (10 items), physical function (10 items) and psychosocial function (20 items). It has high internal consistency in patients with chronic fatigue, multiple sclerosis and mild hypertension. Studies have shown that FIS can better reflect the impact of fatigue on the ability of patients to achieve social functions[7], and has good applicability in Chinese patients with cerebral infarction[12], but it can not distinguish between chronic fatigue and depression, and its use is limited in patients with attention disorder.

2 Evaluation method based on physiological and biochemical indexes

2.1 Evaluation method based on physiological indexes

Physiological indexes such as ECG, EMG and muscle oxygen saturation can not only directly reflect the physiological changes of human body and can be monitored in real time, but also have noninvasive detection. Because the degree of physical fatigue can usually be reflected by heart rate, heart rate variability (HRV), muscle state, etc, physiological indicators can accurately reflect the degree of physical fatigue. At present, the evaluation method based on physiological indexes has been applied to the evaluation of PSF and has become a relevant research topic research hotspots in the field.

2.1.1 ECG signal

ECG refers to the potential changes on the body surface during myocardial contraction and relaxation. Because fatigue will disturb the body balance of PSF patients during rehabilitation training, affect autonomic nerves and lead to corresponding ECG changes, the degree of fatigue of PSF patients can be evaluated by observing the corresponding ECG changes, and heart rate and HRV are two representative ECG signals.

Heart rate is the heart beat frequency, and its change is affected by the interaction of sympathetic nerve and parasympathetic nerve; HRV refers to the periodic fluctuation of sinus rhythm in a certain period of time. It is an important index to reflect the tension and balance of sympathetic and parasympathetic nerves. Buchheit et al[13] found that the heart rate is highly correlated with the training load by monitoring the trainer's fatigue state during training. The heart rate is a simple and effective fatigue state evaluation index, and HRV is a non-invasive evaluation index, which can also be used to monitor the trainer's fatigue state during training[14]. Guidi et al[15] found that HRV can effectively and real-time reflect the muscle condition of subjects during training, which provides important help for real-time monitoring of physical fatigue. In addition, HRV combined with blood biochemical indexes has certain

application value in the early diagnosis of physical fatigue[16].

2.1.2 EMG signal

Surface electromyographic signal (sEMG) refers to the bioelectrical signal generated by the activity of neuromuscular system. Because sEMG in patients with PSF will show different characteristics in the process of rehabilitation training with the aggravation of fatigue, sEMG can be used to evaluate PSF. In the study of using sEMG to evaluate the degree of muscle fatigue, it is found that the sEMG spectrum of stroke patients will shift with the increase of muscle fatigue in the recovery period, which is manifested in the decrease of median frequency and average power frequency[17] and the increase of root mean square value[18], in which the average power frequency can more carefully reflect the change of muscle fatigue. Hussain et al[19] monitored the changes of sEMG in triceps brachii during muscle fatigue induced by isometric contraction under 30%, 45% and 60% maximum voluntary contract (MVC) intensity in 25 subjects.The same results suggest that sEMG is a good index to evaluate the degree of muscle fatigue. SEMG monitoring is convenient, non-invasive, time-saving and sensitive, not easy to be disturbed and easy to be accepted by patients. It is widely used in the evaluation of physical fatigue, but its evaluation of physical fatigue in stroke patients can not be quantified.

2.1.3 Muscle oxygen saturation

Muscle oxygen saturation refers to the proportion of hemoglobin carrying oxygen in muscle tissue, which can reflect the relative changes of oxygen supply and oxygen consumption in human skeletal muscle blood. It is an important index to reflect the state of muscle metabolism. Oxygen is necessary for human life activities and plays an important role in the process of energy metabolism. The oxygen in the muscle tissue of stroke patients will be greatly consumed in the process of rehabilitation training to meet the energy needs of the body, and the muscle oxygen saturation will gradually decrease with the process of rehabilitation training, which will lead to the energy generation of muscles through anaerobic respiratory metabolism and lactic acid accumulation, and finally lead to the aggravation of physical fatigue in stroke patients. At present, near infrared spectroscopy has replaced the traditional, invasive and delayed blood sample collection technology and become the main means to detect or monitor muscle oxygen saturation in real time.Taelman et al[20] carried out fatigue test on subjects by using near infrared spectroscopy technology. The results showed that muscle oxygen saturation had a certain relationship with fatigue; Mohamad et al[21] studied 40 subjects by using near infrared spectroscopy. The results showed that muscle oxygen saturation decreased after fatigue, suggesting that muscle oxygen saturation can be used as an objective index to evaluate fatigue; Mori et al[22] analyzed muscle oxygen saturation and sEMG during physical fatigue by using near infrared spectroscopy, and found that muscle oxygen saturation is closely related to sEMG, suggesting that near infrared spectroscopy can be used as a means to evaluate the degree of PSF; Zampella et al[23] found that the combination of sEMG and near infrared spectroscopy can provide more detailed and accurate physical fatigue information, which is conducive to better evaluate the degree of physical fatigue.

2.2 Evaluation method based on biochemical indexes

Because the biochemical indexes of patients with PSF will change significantly, the detection of biochemical indexes is also a commonly used evaluation method of physical fatigue, that is, the evaluation of body fatigue is realized by observing the changes of biochemical indexes. Many studies have shown that the levels of blood glucose and homocysteine are closely related to the degree of fatigue in stroke patients[24-26]; Ormstad et al[27] studied 45 stroke patients and found that blood glucose was positively correlated with the degree of fatigue at 6 and 12 months after stroke; Sarfo et al[28] also found that blood glucose is closely related to the fatigue degree of stroke patients through the study of 60 stroke patients, and blood glucose can be used to evaluate the fatigue degree of stroke patients. A survey of 312 stroke patients found that in addition to blood glucose, blood uric acid was also related to the degree of fatigue in stroke patients [29]. Other studies have shown that the levels of vitamin B12, tryptophan, interleukin-6 and C-reactive protein are also related to the degree of fatigue in stroke patients [30-33]. Chen Zhilin et al[34] found that

after treatment, the level of C-reactive protein in patients with PSF decreased significantly and the degree of fatigue decreased simultaneously.

3 Other evaluation methods

3.1 Ultrasonic image method

In the process of rehabilitation training, the muscles of PSF patients will contract, and fatigue will reduce the contractile capacity of motor units, the smallest functional unit of muscle contraction. However, because PSF patients are required to carry out functional training, in order to make up for the lack of muscle contraction strength, motor units are continuously recruited, the number of muscle fibers gradually increases, and the muscle thickness increases. Ultrasound images can provide muscle morphological information of PSF patients, reflect the changes of muscle structure during rehabilitation training, and then evaluate the fatigue degree of PSF patients.Seyed hoseinpoor et al[35] found by ultrasonic image method that the muscle thickness after fatigue increased compared with that before fatigue, suggesting that fatigue will change the muscle shape; Wen Huiying et al[36] evaluated the degree of physical fatigue by detecting the changes of muscle structure by ultrasonic image method, and obtained the same results as those studied by Seyed hoseinpoor et al[35].Nijholt et al[37] measured muscle thickness by ultrasonic image method and compared it with the results of magnetic resonance imaging, which confirmed that ultrasonic image method has high reliability and validity. Wang Qian et al[38] found that the degree of muscle fatigue is negatively correlated with the ultrasonic image entropy (the ultrasonic image entropy mainly reflects the average information in the ultrasonic image and can be used as a characteristic quantity to study the degree of muscle fatigue), suggesting that the degree of physical fatigue can be evaluated by observing the percentage of decrease in the ultrasonic image entropy;Fujisawa et al [39] comprehensively evaluated the degree of physical fatigue by ultrasonic image method combined with sEMG. The results show that physical fatigue is closely related to the decrease of median frequency slope and the increase of muscle thickness, suggesting that ultrasonic image method combined with sEMG can obtain more fatigue related information,which may make the evaluation results of physical fatigue more accurate and reliable, and ultrasonic image method may become one of the important research directions of sEMG to evaluate physical fatigue.

3.2 Infrared thermography

Due to the compensatory effect, the poor limb function of PSF patients will not only aggravate energy consumption and physical fatigue, but also lead to the change of body surface temperature, and even affect the rehabilitation process of limb function. Infrared thermography is a safe and reliable body surface temperature detection technology, which can effectively reflect the changes of body surface temperature. Hadzi et al[40] explored the relationship between body surface temperature and physical fatigue through infrared thermal imaging technology, and found that body surface temperature can reflect physical fatigue and its degree; Kuniszyk-jo kowiak et al[41] used infrared thermography to evaluate the physical fatigue of 12 subjects and compared it with sEMG. The results showed that there was a significant correlation between body surface temperature and sEMG in most subjects, suggesting that infrared thermography can be used as a supplementary method to evaluate physical fatigue; Priego-quesada et al[42] found that there was a high correlation between the change of body surface temperature and the visual simulation score of fatigue when using infrared thermal imaging technology to evaluate physical fatigue, suggesting that the change of body surface temperature can be used as an evaluation index to evaluate physical fatigue. It should be noted that because the body surface temperature is not synchronized with the patient's fatigue feeling, it is not accurate to take the body surface temperature as the only evaluation index of physical fatigue.

3.3 Muscle state analysis technology

Muscle state analysis technology is also a non-invasive detection technology, which mainly reflects muscle function and physical fatigue by measuring muscle reaction time, contraction time, relaxation time and radial displacement[43]. However, at present, there are few research reports on the application of muscle state analysis technology in stroke patients. In addition, facial movement (such as yawning), decreased exercise ability and

inattention can also reflect the degree of physical fatigue to a certain extent. However, these performances are rarely used as the evaluation index of physical fatigue because of their low persuasion and poor specificity.

4 Summary and Prospect

To sum up, accurate evaluation of PSF is of great significance for the rehabilitation treatment of stroke patients, but the scale evaluation method of PSF and the evaluation method based on physiological and biochemical indicators can not comprehensively and accurately evaluate the physical fatigue. The combination of scale evaluation method and evaluation methods based on physiological and biochemical indexes may be an important means to evaluate the physical fatigue of PSF patients efficiently and comprehensively.It is believed that with the deepening of the research on PSF and the further development of physical fatigue evaluation methods, the physical fatigue evaluation methods of PSF patients will be improved day by day, and will be conducive to the clinical formulation of positive and effective intervention measures, so as to effectively reduce the pain of PSF patients, improve the quality of life of patients, and reduce the burden of patients' families and society.

Author's contribution: Ren Siqiang is responsible for the conception and design of the article, literature / data collection and sorting, and writing the article; Zhang Qian and Dai Yuxi revised the article and English; Zhen Xicheng is responsible for the quality control and revision of the article, and is responsible for the overall supervision and management of the article.

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Literature retrieval strategy of this article: Use "stroke", "cerebral hemorrhage", "cerebral infarction", "cerebrovascular accident", "apoplexy", "fatigue", "physical fatigue" and "evaluation" as keywords to search CNKI, Weipu.com, Wanfang Data Knowledge Service The platform and PubMed screened the relevant literature in the past 10 years, and used the induction method to analyze the final included literature. Inclusion criteria: (1) The language is Chinese or English; (2) The research type is clinical trial or evidence-based medicine research; (3) The research content involves the evaluation method of physical fatigue in stroke patients. Exclusion criteria: (1) Improper selection of statistical methods; (2) Only abstract but no full text; (3) Repeated publication.

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