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Original Article

Assessing the effectiveness of biofeedback therapy in the rehabilitation of limb motor dysfunction after stroke and the influencing factors of disease-related shame

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Abstract: Objective: To evaluate the effectiveness of biofeedback therapy in the rehabilitation of limb motor dysfunction after stroke and the factors influencing disease-related shame. Methods: Medical records of 118 patients with limb motor dysfunction after stroke, treated in 521 Hospital of the Norinco Group from October 2019 to November 2022, were collected. The 56 patients in control group received conventional rehabilitation training, while the other 62 patients in observation group received electromyographic biofeedback therapy in addition to conventional treatment. The therapeutic effects of both groups were evaluated and compared after 4 weeks of treatment. Changes in FMA (Fugl-Meyer Motor Function Assessment Scale), mRS (Modified Rankin Scale), ADL (Activities of Daily Living Scale), and SSS (Stroke Stigma Scale) were compared before and after treatment. Multivariate logistic regression analysis was used to analyze the factors influencing disease-related shame after treatment. The effectiveness of risk factors in predicting disease-related shame was analyzed using receiver operating characteristic (ROC) curves. Results: Upon intervention, significant gains were noted in FMA and ADL scores, with reductions in mRS and SSS ($P<0.0001$). After 4 weeks, the observation group showed higher FMA and ADL scores and lower mRS and SSS ($P<0.0001$ for FMA and ADL; $P<0.05$ for mRS and SSS). Logistic regression identified age ≥60 (OR 8.045, $P<0.001$), income <4000 yuan (OR 0.187, $P=0.002$), and pretreatment ADL (OR 0.047, $P<0.001$) as predictors of disease-related shame. The AUC for age, household monthly income, and pretreatment ADL score were 0.595 ($P=0.089$), 0.608 ($P=0.053$), and 0.750 ($P<0.001$), respectively, demonstrating pretreatment ADL score as the most accurate predictor of disease-related shame. Conclusions: Electromyographic biofeedback therapy has a significant effect on the rehabilitation of stroke patients, especially on motor recovery and activities of daily living. Age, monthly family income and pre-treatment ADL scores are key factors influencing disease-related shame.

Keywords: Biofeedback therapy, stroke, limb motor dysfunction, rehabilitation, disease-related shame

Introduction

Following a stroke, patients may experience a variety of clinical manifestations depending on the location and severity of the stroke [1]. For example, some patients may experience partial or complete loss of body sensation, slurred speech, facial drooping, dysphagia, and motor dysfunction [2]. Limb dysfunction occurs in 55% to 75% of cases, making it one of the most severe functional impairments after stroke. It often manifests as abnormal muscle tone, decreased limb flexibility, gait abnormalities, joint pain, and balance problems [3, 4]. Due to the potential inability of stroke patients to perform independent household and social activities, coupled with the need for prolonged hospitalization and home care, their self-care abilities in later life are significantly impaired, leading to a drastic decline in quality of life [5]. Therefore, rehabilitation of limb dysfunction after stroke is a primary consideration to

improve patient quality of life and reduce medical costs.

There are numerous therapeutic techniques and methods available to rehabilitate limb dysfunction after stroke, such as functional electrical stimulation, physical therapy, traditional Chinese massage, and proprioceptive neuromuscular facilitation [6]. The rehabilitation process often requires one-on-one training with a therapist, and many patients tend to become anxious and resistant, which affects the overall therapeutic outcome [7]. Therefore, there's an urgent need to explore new and clinically applicable rehabilitation strategies. In clinical practice, specific rehabilitation techniques are employed to improve patients' limb function. Currently, popular rehabilitation methods include electrical stimulation, Bobathel techniques, and Brunnstorme methods [8]. Although these techniques can improve some functional impairments, they often fail to tailor exercise programs to the patient's specific muscle strength, mobility, and other physiological characteristics, which may be a reason for suboptimal post-rehabilitation outcomes [9]. In recent years, electromyographic biofeedback therapy has been widely used in clinical settings, especially for patients with post-stroke hemiplegia [10]. This method amplifies, converts, or simulates the body's electromyographic signals and transforms them into recognizable light, sound, images, or curves to help patients better control muscle and joint movements [11]. As a form of biofeedback therapy, electromyographic biofeedback has been shown to be effective in various conditions and has been widely used in clinical rehabilitation [12]. However, concrete research evidence on the actual effects of biofeedback therapy on the rehabilitation of limb dysfunction in stroke patients is still lacking. Disease-related shame refers to the mental embarrassment that patients feel about their illness. Goffman first introduced this concept and defined it as a psychological state in which individuals feel isolated, stigmatized, and labeled because of certain diseases, leading to an inherent sense of shame [13]. Middle-aged and elderly patients, often uneducated about their condition, tend to misinterpret the prognosis, leading to extreme treatment demands or self-defeatist attitudes that affect disease management.

Stroke-related limb dysfunction severely impacts patients' quality of life, and existing rehabilitation plans are not fully satisfactory. At the same time, disease-related shame is a common and often overlooked problem among stroke patients. This study, through a retrospective analysis of stroke patients treated with biofeedback therapy in 521 Hospital of the Norinco Group from 2018 to 2022, aims to evaluate the effectiveness of this therapeutic technique in improving limb function and activities of daily living. In addition, this study also aims to analyze the impact of the therapy on disease-related shame and its associated factors, providing a basis for optimizing stroke rehabilitation.

Materials and methods

Sample source

A retrospective analysis was performed on the medical records of 168 patients with post-stroke limb motor dysfunction, who were treated in 521 Hospital of Norinco Group from October 2019 to November 2022. The current study was conducted with the approval of the Medical Ethics Committee of the 521 Hospital of Norinco Group.

Inclusion and exclusion criteria

Inclusion criteria: 1. patients who met the clinical criteria of post-stroke hemiplegia [14]; 2. patients who had the first episode of post-stroke hemiplegia with onset within one month; 3. patients with complete clinical data available; 4. patients with limb movement dysfunction after stroke; 5. patients who received treatments in the 521 Hospital of the Norinco Group.

Exclusion criteria: 1. patients with serious dysfunction of major organs such as heart, lungs, liver and kidneys; 2. patients with malignant tumors; 3. patients with severe cognitive dysfunction; 4. patients with serious orthopedic conditions; 5. patients with age <18 years; 6. pregnant women.

Sample selection and grouping

We evaluated the patient data according to the inclusion criteria and included 168 patients who met the requirements. Then, a total of 50 non-compliant samples were excluded accord-

ing to the exclusion criteria: 15 cases due to severe vital organ dysfunction, 8 cases due to malignancy or other severe complications, 12 cases due to severe cognitive dysfunction, and 13 cases due to severe orthopedic disease. There was 1 case with age <18 years and 1 women during pregnancy. Finally, 118 cases were included in the study. Among them, 56 patients received conventional rehabilitation training (control group), and the remaining 62 patients received electromyographic biofeedback therapy based on conventional treatment (observation group).

Clinical data collection

Clinical data and laboratory indicators were collected from electronic medical records and outpatient follow-up records. The data included age, sex, marital status, monthly family income, occupation, education level, living environment, history of diabetes, hypertension, and type of stroke. In addition, scores of FMA (Fugl-Meyer Motor Assessment Scale), mRS (Modified Rankin Scale), ADL (Activities of Daily Living Scale), and SSS (Stroke stigma scale) were collected during the treatment period.

Functional assessment

The FMA was used to assess motor function, including upper and lower limbs. The upper limb score has a maximum of 66 points and the lower limb score has a maximum of 34 points, with scores directly proportional to motor ability [15].

ADL assesses an individual's basic self-care activities of daily living, with a maximum score of 100. Higher scores indicate better daily living skills [16].

SSS assesses the level of shame in stroke patients using a 5-point Likert scale. Scores ranged from 1 to 5, with higher scores indicating greater shame [17].

The mRS evaluates physical disability status with a 5-point grading system. A higher score indicates a worse prognosis [18].

Treatment protocol

The control group underwent rehabilitation training to increase muscle strength and received training for limb extension and coordination. This included turning exercises, Bobath handshake exercises, and transitioning from bed to semi-recumbent to sitting position, with additional weight-bearing exercises. The training lasted 25-28 min/day, once a day, for 4 weeks.

The observation group, in addition to the above, received electromyographic biofeedback therapy (Biostimulation Feedback Instrument, Xiangyu Medical Rehabilitation Equipment, XY-K-FEZL-II) (The biofeedback therapy lasted 50 min/session, once a day, five times a week, for 4 weeks). After cleaning and drying the skin, tripolar electrodes were placed on the lower limb of the affected side, another electrode was placed on the lower end of the tibialis anterior muscle, and an auxiliary electrode was placed in a stable motion position. The surface electrodes were connected to the biofeedback stimulator, and electromyographic signals from muscle movement could be viewed on a screen. Patients were encouraged to perform dorsiflexion exercises. When the surface electromyographic value rose to a preset threshold, the system delivered a 9-second electrical stimulus with a 15-second interval at a frequency of 55.6 Hz. Patients were then instructed to increase the signal strength above this threshold. Once the patient achieved a new peak signal, this higher value was established as the new baseline. The treatment session continued with this approach, adjusting the baseline upward each time it was exceeded, until the patient could no longer surpass the newly established baseline, marking the completion of a session.

Observation indicators

Primary outcome measures: Assessment of changes in functional scores before and after treatment (4 weeks). Based on the post-treatment SSS score, patients with scores ≥40 were classified as having high disease-related shame, and those with scores <40 were classified as having low disease-related shame. Logistic regression was used to analyze risk factors for high disease-related shame.

Secondary outcome measures: The differences in clinical data were compared between the control and observation groups.

Table 1. Baseline information

Factor	Control Group (n=56)	Observation Group (n=62)	χ^2 Value	*P* Value
Age			0.112	0.736
≥60 years old	36	38		
<60 years old	20	24		
Gender			0.195	0.658
Male	34	34		
Female	22	26		
Marital Status			0.271	0.602
Married	42	49		
Single	14	13		
Monthly Household Income			0.024	0.875
≥4000 yuan	29	27		
<4000 yuan	27	35		
Occupation			0.188	0.664
Employed	40	42		
Unemployed	16	20		
Education Level			1.549	0.213
≥ High school	37	34		
< High school	19	28		
Living environment			0.988	0.320
City	34	32		
Rural	22	30		
History of diabetes			3.107	0.078
Present	26	19		
Absent	30	43		
History of hypertension			0.800	0.370
Present	29	27		
Absent	27	35		
Type of stroke			1.275	0.258
Ischemic	39	37		
Hemorrhagic	17	25		

Statistical analysis

Statistical analysis was performed with the use of SPSS 26.0 (IBM Corp, Armonk, NY, USA). GraphPad Prism 9 was used for data visualization. Count data were presented as [n (%)], and chi-squared tests were used to compare count data between groups. Measurement data were presented as mean ± SD. Independent samples t-tests were used for between-group comparisons of measurement data, and paired t-tests were used for within-group comparisons. Logistic regression was used to analyze risk factors for high disease-related shame. Receiver operating characteristic (ROC) curves were used to analyze the effectiveness of risk factors in predicting disease-related shame. Differences were considered statistically significant if P<0.05.

Results

Baseline data assessment

We first compared the baseline data of the two groups. The results showed that there were no statistically significant differences between the control and observation groups in terms of age, sex, marital status, monthly family income, occupation, educational level, living environment, history of diabetes, hypertension, and type of stroke (P>0.05, **Table 1**).

Changes in FMA and mRS scores before and after treatment

There were no statistically significant differences in the FMA and mRS scores before the intervention (P>0.05, **Figure 1**). After the interven-

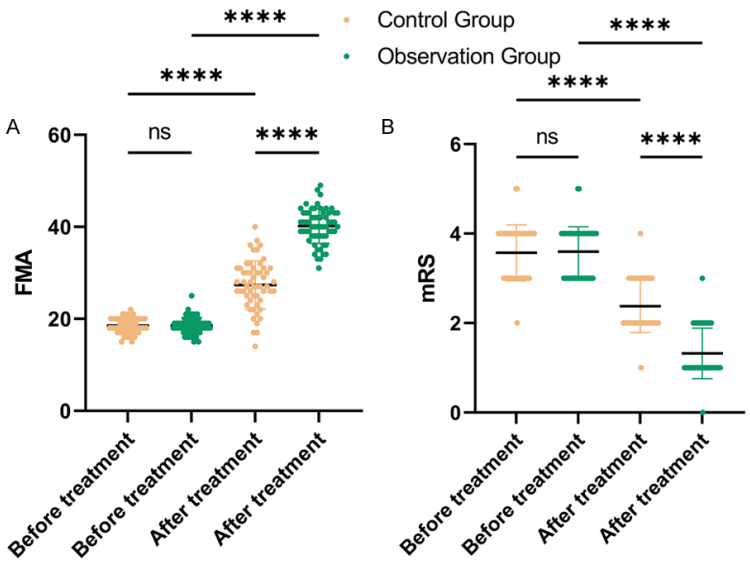

Figure 1. Changes in FMA and mRS scores before and after treatment in patients. A. Changes in FMA scores before and after treatment in control group and observation group. B. Changes in mRS scores before and after treatment in control group and observation group. Note: nsP>0.05, ****P<0.0001; FMA, Fugl-Meyer Motor Function Assessment Scale; mRS, Modified Rankin Scale.

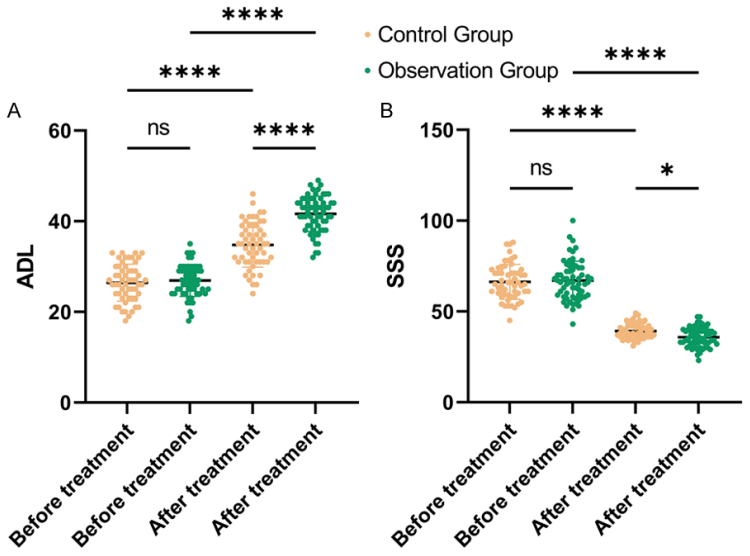

Figure 2. Changes in ADL and SSS scores before and after treatment in patients. A. Changes in ADL scores before and after treatment in control group and observation group. B. Changes in SSS scores before and after treatment in control group and observation group. Note: nsP>0.05, *P<0.05, ****P<0.0001; ADL, Activities of Daily Living Assessment Scale; SSS, Stroke Stigma Scale.

tion, the FMA scores of both groups increased significantly compared to those before the intervention (P<0.0001, **Figure 1**), while the mRS scores significantly decreased (P<0.0001, **Figure 1**). Furthermore, 4 weeks after the intervention, the FMA scores of the observation group were significantly higher than those of the control group, while the mRS scores were significantly lower, showing statistically significant differences (P< 0.0001, **Figure 1**).

Changes in ADL and SSS scores before and after treatment

There were no statistically significant differences in the ADL and SSS scores before the intervention (P>0.05, **Figure 2**). After the intervention, the ADL scores of both groups increased significantly compared to those before the intervention (P<0.0001, **Figure 2**), while the SSS scores significantly decreased (P<0.0001, **Figure 2**). Furthermore, 4 weeks after the intervention, the ADL score of the observation group was significantly higher than that of the control group, while the SSS scores were significantly lower, showing statistically significant differences (P<0.05, **Figure 2**).

Analysis of risk factors for disease-related shame

Based on the disease-related shame scores, patients with scores <40 were included in a low disease shame group (n= 76), and those with scores ≥40 were in a high disease shame group (n=42). On comparison, a significantly higher proportion of patients in the high disease shame group were aged ≥60 years, with a monthly family income of <4000 yuan, and had an educational level below high school. In addition, the pretreatment ADL score of the high disease shame group was significantly lower than that of the low disease shame group, showing a statistically sig-

Table 2. Comparison of clinical data between different disease shame groups

Factor	Low Disease Shame Group (n=76)	High Disease Shame Group (n=42)	χ^2/t Value	*P* Value
Age			9.278	0.002
≥60 years old	40	34		
<60 years old	36	8		
Gender			0.735	0.391
Male	46	22		
Female	30	20		
Marital status			1.196	0.274
Married	61	30		
Single	15	12		
Monthly household income			5.458	0.019
≥4000 yuan	46	16		
<4000 yuan	30	26		
Occupation			2.536	0.111
Employed	49	33		
Unemployed	27	9		
Education level			9.986	0.002
≥ High school	55	18		
< High school	21	24		
Living Environment			1.828	0.176
City	46	20		
Rural	30	22		
History of diabetes			0.616	0.432
Present	27	18		
Absent	49	24		
History of hypertension			0.553	0.456
Present	38	18		
Absent	38	24		
Type of stroke			2.646	1.627
Ischemic	53	23		
Hemorrhagic	23	19		
Treatment program			3.808	0.051
Control group	31	25		
Observation group	45	17		
Pre-treatment FMA score	18.12±1.4	18.72±1.78	1.901	0.059
Pre-treatment mRS score	3.64±0.66	3.55±0.55	0.794	0.428
Pre-treatment ADL score	24.64±2.89	27.82±3.72	4.786	<0.001

Note: FMA, Fugl-Meyer Motor Function Assessment Scale; mRS, Modified Rankin Scale; ADL, Activities of Daily Living Assessment Scale.

nificant difference (P<0.05, **Table 2**). After data assignment (**Table 3**), multivariate logistic regression analysis revealed that age, monthly family income, and pretreatment ADL scores were independent risk factors influencing patients' disease-related shame (P<0.01, **Table 4**).

Efficacy of risk factors in predicting disease-related shame

Finally, we used ROC curve analysis to evaluate the efficacy of age, monthly family income, and pretreatment ADL scores in predicting disease-related shame. The ROC curve analysis showed

Table 3. Assignment table

Factor	Assignment
Age	≥60 years old =1, <60 years old =0
Monthly household income	≥4000 yuan =1, <4000 yuan =0
Education level	≥ High school =1, < High school =0
Pre-treatment ADL score	≥27.5=1, <27.5=0
Disease-related shame	Low Disease Shame =1, High Disease Shame =0

Note: ADL, Activities of Daily Living Assessment Scale.

Table 4. Logistics regression analysis

Factor	β Value	Standard Error	χ^2 Value	*P* Value	OR Value	95% CI	
						Lower Limit	Upper Limit
Age	2.085	0.574	13.213	<0.001	8.045	2.614	24.76
Monthly household income	-1.679	0.536	9.820	0.002	0.187	0.065	0.533
Education level	0.716	0.521	1.887	0.170	2.046	0.737	5.683
Pre-treatment ADL score	-3.048	0.710	18.422	<0.001	0.047	0.012	0.191

Note: ADL, Activities of Daily Living Assessment Scale.

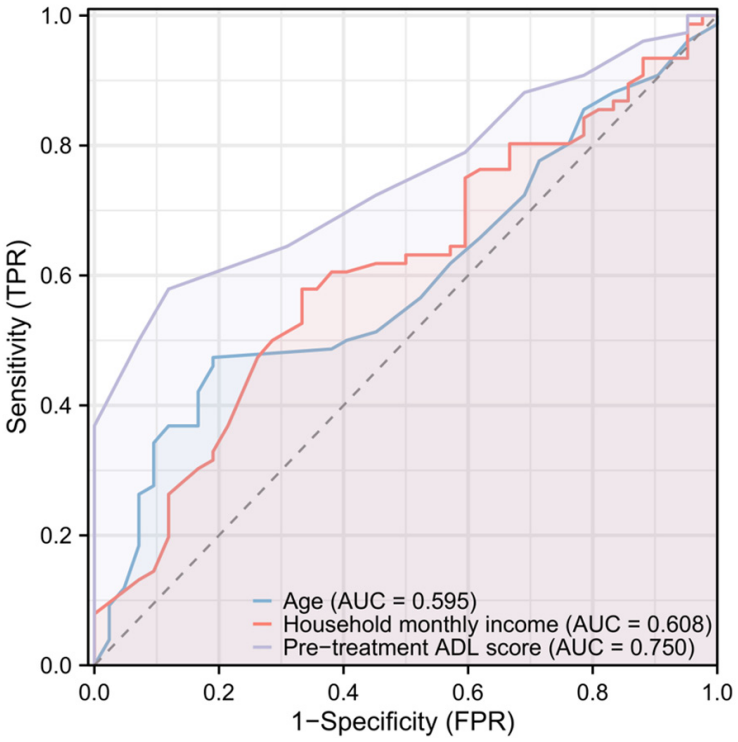

Figure 3. ROC curve of age, monthly household income, and pre-treatment ADL score in predicting patient's disease-related shame. Note: ADL, Activities of Daily Living Assessment Scale; ROC, Receiver Operating Characteristic Curve.

that the area under the curve (AUC) for age, monthly family income, and pretreatment ADL scores were 0.595, 0.608, and 0.750, respectively (**Figure 3**; **Table 5**). Among them, the AUC for pretreatment ADL score was significantly higher than that for age and monthly family income, making it a better indicator for predicting disease-related shame (**Table 6**, P<0.05).

Discussion

According to data from the Geriatric Disease Association of China, in 2018, the incidence of stroke among people aged 60 years and above was 242.3/100,000, which puts great burden on families and society [19]. Hemiplegia caused by stroke is closely related to neural damage. In the acute phase of stroke, insufficient blood supply to the brain leads to nerve cell damage and myelin cell death, which subsequently affects nerve conduction and results in functional impairment [20]. Therefore, as soon as the stroke condition stabilizes, rehabilitation should be started via guided training, Bobath method, Brunnstorm method etc.

In this study, we found that the FMA score of the observation group after intervention was significantly higher than that of the control group, while the mRS score was significantly lower. These results indicate that the patients

Table 5. ROC parameters of factors predicting disease-related shame

Predictive Variable	Area Under Curve	95% CI	Cut-off Value	Sensitivity	Specificity	Youden Index	*P* Value
Age	0.595	0.491-0.698	59.500	47.37%	80.95%	28.32%	0.089
Household monthly income	0.608	0.503-0.713	3750.000	57.90%	66.67%	24.56%	0.053
Pre-treatment ADL score	0.750	0.664-0.835	27.500	57.90%	88.10%	45.99%	<0.001

Note: ADL, Activities of Daily Living Assessment Scale; ROC, Receiver Operating Characteristic Curve.

Table 6. Delong test analysis of differences in area under curve of risk factors

Variable 1	Variable 2	Statistic	*P* Value
Age	Household monthly income	-0.17441	0.861
Age	Pre-treatment ADL score	-2.1893	0.028
Household monthly income	Pre-treatment ADL score	-1.9626	0.049

who received electromyographic biofeedback therapy made more significant progress in recovering motor function. At the same time, they also have better recovery in terms of physical disability or functional impairment. In addition, the ADL score of the observation group was also significantly higher than that of the control group, indicating that they achieved better results in daily self-care ability. At the same time, the observation group also showed better results in SSS score, meaning that these patients feel less psychological shame or frustration about their condition.

Traditional rehabilitation training is an essential tool for patients to improve muscle strength and regain limb function. Related methods mainly focus on limb stretching and coordination function training, using various means, such as turning exercises and Bobath handshake exercises, to improve the patient's physical function [21]. However, traditional training has its limitations. First, the rehabilitation effect and speed are influenced by various external and internal factors, such as the patient's physical condition, continuity and intensity of training. In addition, patients find it difficult to receive real-time feedback during exercise, which may affect their motivation [22]. In contrast, electromyographic biofeedback therapy offers a new perspective for rehabilitation. This method monitors electromyographic signals in real time through a biofeedback device, providing patients with immediate feedback. When the electromyographic signal generated by the muscles reaches a preset threshold, the system immediately delivers an electrical stimulus. This real-time feedback can more accurately guide patients in rehabilitation training [23]. In addition, by recording the highest signal of the action and using it as a threshold, this method encourages patients to continue their efforts, thereby increasing the intensity and effect of the movement [24]. This therapy not only provides patients with more precise rehabilitation guidance, but also better motivates patients to actively participate in treatment, which significantly improves rehabilitation outcomes.

As reported by Wang et al. [25], we examined the effects of combining botulinum toxin A with electromyographic biofeedback therapy. The findings indicated that the group receiving both botulinum toxin A and electromyographic biofeedback therapy showed superior improvements in spasticity, limb motor function, and activities of daily living, when compared to the control group, which only received electromyographic biofeedback therapy. It's important to note that while both groups benefited from electromyographic biofeedback therapy, the additional administration of botulinum toxin A in the study group was associated with more significant advancements, particularly in terms of motor recovery and reduction in spasticity. This suggests that the combination of both treatments may offer enhanced therapeutic benefits over electromyographic biofeedback therapy alone. This is consistent with our findings that patients who received electromyographic biofeedback therapy made greater progress in motor recovery. This may be because electromyographic biofeedback therapy provides patients with real-time feedback, allowing them to receive more precise rehabili-

tation training. Furthermore, the study of Murrell et al. [21] used the Bayesian network meta-analysis method to investigate the effect of electromyographic biofeedback therapy combined with rehabilitation training on upper limb motor function and pain relief in patients with different degrees of motor dysfunction after stroke. This is not entirely relevant to our discussion, but offers a perspective on another rehabilitation method. This suggests that other methods besides electromyographic biofeedback therapy can also help stroke patients recover.

Shame after stroke is common among patients, with the highest scores in the physical impairment dimension, followed by social interaction, self-perception, and experiences of discrimination [26]. Functional impairments after stroke, which affect the patient's physiological function and self-image, combined with the prolonged recovery process, further exacerbate patient's sense of shame [27, 28]. In this study, we found that age, monthly family income, and pretreatment ADL scores were risk factors that affect the patient's sense of shame. First, with increasing age, the physiological functions of the body gradually decline, leading to a reduced ability to recover. Elderly people may be more concerned about their physical condition, leading to increased shame [29]. In addition, they may be more concerned about the opinions and evaluations of others, fearing to become a burden to their families and the society. Second, family's economic situation has a direct impact on the patient's treatment and recovery. Patients with a lower monthly family income may not be able to afford the high medical expenses, limiting their treatment and recovery. This economic pressure may increase the patient's sense of shame and fear of being an economic burden on the family [30]. Finally, the ADL score directly reflects the patient's ability to perform activities of daily living [31]. A lower score indicates poorer ability to perform activities of daily living, leading to increased dissatisfaction about their physical condition. When patients cannot perform activities of daily living independently, they may feel that they are a burden to their family and worry about others' opinions and judgments, leading to a sense of shame. At the end of our study, we analyzed the effectiveness of the three risk factors in predicting the patient's sense of shame. The results showed that the pre-treatment ADL score was the most effective indicator for predicting the patient's sense of shame, possibly because it directly reflects the patient's daily living ability and rehabilitation needs, which are directly related to the onset of shame.

However, this study has some limitations. First, because this research is retrospective, it relies mainly on existing data and records. This may lead to the omission of some important information or variables, or there may be bias and incompleteness in the data. Second, a major limitation of retrospective research is the inability to determine causality. Although we found associations between certain variables, we cannot determine whether one variable actually caused the change in another. Finally, due to the retrospective nature of this study, its time span may be limited by the data source. This means that we may not be capturing long-term rehabilitation effects or changes in shame. We hope to conduct randomized controlled trials or cohort studies in future research to refine our research conclusions.

In conclusion, electromyographic biofeedback therapy has a significant effect on the rehabilitation of stroke patients, especially in terms of motor recovery and activities of daily living. At the same time, age, monthly family income, and pre-treatment ADL scores are key factors that affect the patient's sense of disease-related shame. Future research should further explore the in-depth relationship between these factors and disease-related shame to provide more precise rehabilitation guidance.

Disclosure of conflict of interest

None.

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