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ORIGINAL RESEARCH

Clinical Effect of Motor Imagery Combined with Whole-Body Vibration Therapy on Elderly Patients with Limb Dysfunction After Stroke

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Objective: To explore the clinical efficacy of motor imagery (MI) combined with whole-body vibration (WBV) therapy on elderly patients with post-stroke limb dysfunction.

Methods: This was a retrospective case-control study. Elderly stroke patients with limb dysfunction were divided into a control group (traditional rehabilitation training) and an observation group (MI combined with WBV therapy). Outcomes assessed included upper limb muscle strength/function, event-related potentials (P300), gait indicators, balance, and self-care ability before and after the intervention.

Results: There were a total of 139 patients, with 67 in the control group and 72 in the observation group. After intervention, the upper limb muscle strength and function, event-related potentials, gait indicators, balance ability, and self-care ability of both groups improved compared to before intervention, and the observation group was better than the control group.

Conclusion: The combination of MI and WBV therapy was superior to traditional rehabilitation alone in improving limb function, cognitive responses (P300), gait, balance, and self-care ability in elderly stroke patients.

Keywords: motor imagery, whole-body vibration, post-stroke limb dysfunction, elderly

Introduction

Stroke is a common disease type in neurology.[1] In recent years, it has been influenced by various factors such as the development of unhealthy lifestyle habits and changes in dietary structure. This has led to a continuous increase in the incidence rate of stroke, and the number of patients is getting younger.[1,2] Meanwhile, with the advancement of medical technology, the effectiveness of stroke treatment has been significantly improved.[3] But survivors still have varying degrees of limb dysfunction, posing a huge threat to the quality of life and physical and mental health of patients.[3,4] Research has shown that early functional rehabilitation exercises for patients after stroke can help improve their overall functional status.[3,4] Recent studies have confirmed the efficacy of combined MI and WBV therapy in improving neuromuscular control and cognitive-motor integration in stroke patients. Elderly patients, specifically targeted in our study, are more vulnerable due to age-related neuromuscular decline, thus necessitating tailored rehabilitation strategies.[5]

Both motor imagery and WBV therapy are important rehabilitation training measures in clinical practice.[6,7] Among them, MI is repeated to improve motor ability without any motor output. But this can improve limb motor function by activating a specific area in the brain based on motor memory.[6] The WBV therapy is a method of restoring neuromuscular function by inducing whole-body or local muscle oscillations and adaptive changes in the central nervous system through exogenous mechanical vibration and resistance load stimulation.[8,9]

There is limited literature confirming the effects of MI combined with WBV therapy on functional rehabilitation in elderly stroke patients with limb dysfunction. Therefore, this study intends to retrospectively analyze the clinical data of elderly stroke patients with limb dysfunction in our hospital. This aims to clarify the intervention effect of combining MI with WBV therapy.

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Materials and Methods

Research Design and Patients

This is a retrospective case-control analysis. Retrospective selection of records of elderly post-stroke limb dysfunction patients admitted to The Sixth People's Hospital of Chongqing from October 2022 to May 2024. According to the patient's rehabilitation records, they were divided into a control group (traditional rehabilitation training) and an observation group (MI combined with WBV therapy). Inclusion criteria: 1) Meet the diagnostic criteria for stroke;[1] 2) Previously had normal limb function, but experienced varying degrees of limb dysfunction after stroke; 3) Age ≥ 60 years old; 4) First onset of illness; 5) Complete clinical data. Exclusion criteria: 1) Patients with mental disorders; 2) Patients with visual and auditory impairments; 3) Patients with contraindications to WBV training (such as implantation of pacemakers, gallstones, fractures); 4) Patients with peripheral neuropathy; 5) Patients with tachycardia/bradycardia.

Intervention Methods

Traditional Rehabilitation Training

1) Exercise therapy, which assists patients with limb movement function exercises in an active/passive manner; Including transfer training, balance training, muscle strength induction exercises, nerve stimulation techniques, etc; 2) Homework therapy, referring to the patient's upper limb functional status, adopts relevant props to carry out exercises and restore the function of the affected upper limb; 3) Standing exercise, stand on a stand, maintain an upright body, slightly spread your legs apart, and place your weight on the affected limb as much as possible; 4) Squat practice, keep your feet shoulder width apart, squat for 5 seconds, then slowly stand up. The above training is 45 minutes per session, 3 sessions per day. Lasting for 3 months.

MI Combined with WBV Therapy

1) MI: Firstly, explain to the patient the rehabilitation process and precautions for post-stroke limb dysfunction, and obtain their understanding and cooperation; Then proceed with the exercise step by step. i. Clarify the left and right limbs: The rehabilitation therapist selects 20 different cards of a unilateral limb, and the patient independently identifies whether it is the left or right limb; And record the patient's reaction time and judgment accuracy for each card; ii. Exercise of motor imagination: Select a mirror therapy device based on the patient's limb function status; And screen 10 body movement videos closely related to daily life scenarios, play them 3 times; Guide patients to imagine the actions of others in the video as themselves performing functional training based on text and voice prompts while watching; iii. Mirror therapy: assist patients in taking a sitting position; The rehabilitation therapist places a 120 cm × 60 cm mirror in the anteroposterior mid sagittal position, with the back facing the affected limb and the mirror facing the healthy limb; Guide the patient's trunk and head to slightly lean towards the healthy side, ensuring that they can clearly see the imaging of limb activity on the healthy side; And gently and slowly carry out hip joint adduction, abduction, flexion and extension exercises; Perform knee joint extension and flexion; Perform finger joint, shoulder, wrist, elbow abduction, adduction, rotation, flexion and extension exercises, forearm pronation and supination exercises in all directions; Imagine limb movements within the mirror as synchronized movements of the healthy and affected limbs; Try to make the affected limb imitate the mirror movement of the healthy limb as much as possible; 10 sets/time, 30 minutes/time, 5 days/week. 2) Gradual whole-body vertical vibration: The Galileo Delta A (Soreha, Germany) vibration therapy device was selected as the equipment; The patient stands on the vibration therapy platform; The patient faces the mirror and places their body's center of gravity on the midline; Slightly bend both knees at an angle of about 20°to 30°, with both feet in a neutral position; Grasp the armrest in front of the vibrator with both hands and secure it with a pelvic sling; Set the vibration frequency to 30 Hz and the amplitude to 2 mm; 5 sets/time, 2 minutes/set; Once a day, 6 days per week. Lasting for 3 months.

Collect Information

Collect clinical data of patients from electronic medical records: 1) Collect basic characteristics of patients. Including age, gender, disease duration, affected side, stroke type, and Brunnstrom staging. 2) Upper limb muscle strength and function. Upper limb muscle strength is evaluated through manual muscle testing (MMT); No measurable muscle contraction at level 0 (0 points); There is slight contraction, but it is difficult to cause joint movement, which is rated as level 1 (1 point); Full range joint movement during weight loss is rated as level 2 (2 points); Capable of performing full range joint movements against gravity, but difficult to resist resistance at level 3 (3 points); The ability to resist gravity and certain resistance movements is rated as level 4 (4 points); The ability to resist gravity and sufficient resistance is rated as level 5 (5 points). The upper limb function was evaluated using the Fugl-Meyer Upper Limb Scale (FM-UL) and the Action Research Arm Test (ARAT). Among them, FM-uL includes 33 entries; A total of 66 points, the higher the score, the better. ARAT includes tests in four dimensions: gross motor skills, pinching, gripping, and grasping; A total of 57 points, the higher the score, the better. 3) Event-related potential. Event-related potentials (P300) were recorded using a Medtronic evoked potential/electromyography system. Electrodes were placed according to the International 10–20 EEG electrode placement system, with active recording electrodes positioned at Cz, reference electrodes at linked mastoids (M1, M2), and a ground electrode placed on the forehead (Fpz). Participants were comfortably seated and instructed to perform an auditory oddball task. This task consisted of frequent (80%) standard tones (1000 Hz) and infrequent (20%) target tones (2000 Hz), presented randomly at an interstimulus interval of 1 second through headphones at an intensity of 70 dB. Participants were asked to press a button quickly upon hearing the infrequent target tones, ensuring active cognitive engagement. P300 latency (ms) and amplitude (μV) were analyzed, taking the average response from 200 ms pre-stimulus to 800 ms post-stimulus. Each participant completed two blocks of 50 stimuli, and averages were taken from correctly identified target stimuli. 4) Gait indicators (step speed, step width, step length). Spread white powder evenly on the ground and let the patient walk barefoot; Measure step width and step length; Measure the patient's walking speed using the fastest walking speed of 10 meters, and record the time it takes for the lower limbs to cross the 3-meter mark line and exit it. The "white powder method" has shown strong correlation (r>0.9) with gold-standard gait analysis systems like GAITRite®.[10] 5) Balance ability and self-care ability. Balance ability is evaluated based on the Berg Balance Scale (BBS), which includes 14 functional activity items related to balance; The score range is 0–56 points, and the higher the score, the stronger the balance ability. Self care ability is evaluated based on the Barthel Index (BI) scale, with a total of 100 points; The higher the score, the stronger the self-care ability. Primary outcomes: upper limb muscle strength/function (MMT, FM-UL, ARAT), event-related potentials (P300 amplitude/latency). Secondary outcomes: gait indicators (speed, width, length), balance (BBS), activities of daily living (BI).

Statistical Analysis

All data analysis was conducted using SPSS 25.0 software (IBM Corp, Armonk, NY, USA). Use Shapiro Wilk test to evaluate the normality of the evaluation data. Normal distribution data is represented by mean ± standard deviation (SD), independent sample *t*-test is used for inter group comparison, and paired *t*-test is used for intra group comparison before and after; Non normally distributed data are represented by median and interquartile range. Mann Whitney *U*-test is used for inter group comparisons, and Wilcoxon signed rank test is used for intra group comparisons. The count data is represented by the number of cases, using chi square test. When P<0.05, the difference is considered statistically significant. Effect sizes (mean differences, 95% confidence intervals) were reported alongside P-values. Multiple comparisons were adjusted using Bonferroni correction to control Type I error.

Results

Patient Characteristics

In this study, a total of 139 patients met the criteria, including 81 males and 58 females; The age range is 60–89 years old, with an average age of 70.90 ± 6.37; The duration of the disease ranges from 1 to 16 months, with an average of 7.81 ± 3.11; 61 cases of limb dysfunction were on the left side, and 78 cases were on the right side; 56 cases were cerebral hemorrhage and 83 cases were cerebral infarction. A total of 84 cases were classified as stage III, 39 cases as stage IV, and 16 cases as stage V in Brunnstrom staging; There were 67 cases in the control group and 72 cases in the observation group. There was no significant difference in basic characteristics such as age, gender, disease duration, affected side, stroke type, and Brunnstrom staging between the two groups (*P*>0.05) (Table 1). No dropouts occurred during the intervention. Missing data were minimal and handled using appropriate imputation methods (mean substitution method).

Table 1 Comparison of Basic Characteristics Between Two Groups

Characteristics	Observation Group (n=72)	Control Group (n=67)	t/χ^2	*P*
Male (Yes), n (%)	43 (59.7)	38 (56.7)	0.129	0.720
Age (years), mean±SD	71.25±6.63	70.52±6.10	0.672	0.503
Disease duration (months), mean±SD	7.53±3.18	8.12±3.04	−1.121	0.264
Affected side, n (%)				
Left	29 (40.3)	32 (47.8)	0.789	0.374
Right	43 (59.7)	35 (52.2)		
Stroke type, n (%)				
Cerebral hemorrhage	32 (44.4)	24 (35.8)	1.073	0.300
Cerebral infarction	40 (55.6)	43 (64.2)		
Brunnstrom staging, n (%)				
III	43 (59.7)	41 (61.2)	2.352	0.309
IV	18 (25.0)	21 (31.3)		
V	11 (15.3)	5 (7.5)		

Upper Limb Muscle Strength and Function

Table 2 shows that there was no significant difference in MMT, FM uL, and ARAT scores between the two groups before intervention ($P>0.05$); After intervention, the scores of MMT, FM uL, and ARAT in both groups increased compared to before intervention, and the observation group was higher than the control group ($P<0.05$).

Event Related Potentials

Table 3 shows that there was no significant difference in P300 amplitude and P300 latency between the two groups before intervention ($P>0.05$); After intervention, the amplitude of P300 in both groups increased compared to before intervention, and the latency of P300 decreased compared to before intervention; Moreover, the amplitude of P300 in the observation group was greater than that in the control group, and the latency of P300 was smaller than that in the control group ($P<0.05$).

Gait Indicators

Table 4 shows that there was no significant difference in step speed, step width, and stride length between the two groups before intervention ($P>0.05$); After intervention, the walking speed, step width, and stride length of both groups increased compared to before intervention, and the observation group was larger than the control group ($P<0.05$).

Table 2 Comparison of Upper Limb Muscle Strength and Function Between Two Groups (Scores)

Time	Group	n	MMT	FM-uL	ARAT
Before intervention	Observation group	72	2 (2–2.5)	34.27±4.16	27.66±4.08
	Control group	67	2 (2–2)	33.95±4.38	28.18±3.77
	Z/*t*		−1.897	0.442	−0.758
	P		0.058	0.659	0.450
After intervention	Observation group	72	4 (4–5)^a	49.51±3.85^a	48.53±5.17^a
	Control group	67	4 (3–4)^a	44.07±3.56^a	43.80±6.26^a
	Z/*t*		−5.342	8.592	4.909
	P		<0.001	<0.001	<0.001

Notes: Compared with before treatment in the same group, $^aP<0.05$.
Abbreviations: MMT, manual muscle testing; FM-UL, Fugl-Meyer Upper Limb Scale; ARAT, Action Research Arm Test.

Table 3 Comparison of Event-Related Potentials Between Two Groups

Time	Group	n	P300 Amplitude (uV)	P300 Latency (ms)
Before intervention	Observation group	72	7.29±1.36	408.38±50.20
	Control group	67	7.51±1.18	410.13±46.18
	t		−1.021	−0.215
	P		0.309	0.830
After intervention	Observation group	72	9.69±1.22[a]	348.30±17.17[a]
	Control group	67	8.51±1.05[a]	363.14±18.30[a]
	t		6.125	−4.933
	P		<0.001	<0.001

Notes: Compared with before treatment in the same group, [a]*P*<0.05.

Table 4 Comparison of Gait Indicators Between Two Groups (Scores)

Time	Group	n	Step Speed (m/min)	Step Width (cm)	Stride Length (cm)
Before intervention	Observation group	72	26.91±4.33	8 (7–10)	28.31±5.67
	Control group	67	27.71±4.14	9 (8–10)	27.79±6.22
	Z/*t*		−1.154	−1.588	0.534
	P		0.250	0.112	0.594
After intervention	Observation group	72	37.41±3.66[a]	12.5 (12–14)[a]	36.18±4.47[a]
	Control group	67	33.38±3.75[a]	11 (10–11)[a]	32.37±4.20[a]
	Z/*t*		6.476	−7.875	5.115
	P		<0.001	<0.001	<0.001

Notes: Step speed: The speed at which the patient walks, calculated by dividing the total distance covered by the time taken to walk that distance. The unit is meters per minute (m/min). Step width: The horizontal distance between the two feet during walking, measured from the outer edge of one foot to the outer edge of the other foot. The unit is centimeters (cm). Stride length: The distance covered by one stride, measured from the heel of one foot to the heel of the other foot when the same foot lands again. The unit is centimeters (cm). Compared with before treatment in the same group, [a]*P*<0.05.

Balance Ability and Self-Care Ability

Table 5 shows that there was no significant difference in BBS and BI scores between the two groups before intervention (*P*>0.05); After intervention, the BBS and BI scores of both groups increased compared to before intervention, and the observation group was higher than the control group (*P*<0.05).

Discussion

The results of this study show that compared with conventional rehabilitation training, the intervention of MI combined with WBV therapy has higher benefits for elderly stroke patients with limb dysfunction. Stroke patients suffer from

Table 5 Comparison of Balance and Self Care Abilities Between Two Groups (Scores)

Time	Group	n	BBS	BI
Before intervention	Observation group	72	20.46±5.31	45.77±6.24
	Control group	67	19.97±6.02	46.56±5.92
	t		0.550	−0.786
	P		0.583	0.432
After intervention	Observation group	72	44.71±4.69[a]	70.09±5.16[a]
	Control group	67	39.98±5.10[a]	65.45±4.94[a]
	t		5.734	5.471
	P		<0.001	<0.001

Notes: Compared with before treatment in the same group, [a]*P*<0.05.
Abbreviations: BBS, Berg Balance Scale; BI, Barthel Index.

damage to mechanisms such as interaction inhibition due to abnormal function of central nervous system control pathways in corresponding brain regions. Stroke manifests as sensory and motor dysfunction, abnormal muscle tone, etc.[1] Therefore, effective rehabilitation management should be provided early to ensure the effectiveness of limb function rehabilitation and the prognosis of the disease.[11] In this study, upper limb muscle strength and function significantly improved in the MI combined with WBV therapy group compared to conventional rehabilitation alone. Motor imagery activates cortical motor representations without actual motor execution, enhancing cortical plasticity and improving neuromuscular efficiency.[12] Meanwhile, WBV therapy stimulates proprioceptive afferents and increases muscular activation through tonic vibration reflexes, thereby enhancing neuromuscular coordination and muscle strength.[13,14] The synergistic use of these two modalities appears particularly beneficial for overcoming stroke-induced functional impairments. Electrophysiological improvement was also superior in the MI combined with WBV therapy group, characterized by increased P300 amplitude and decreased latency. MI combined with WBV synergistically improved P300 latency by enhancing cortical plasticity and sensory-motor integration, thus optimizing neuromuscular function. WBV provides sensory-motor input that complements the cortical activation promoted by MI, facilitating neuroplasticity and thus leading to improved cognitive-motor processing speed and efficiency.[15,16]

The study findings indicate superior improvements in gait parameters (speed, width, length) and balance (BBS scores) in patients receiving MI combined with WBV. WBV therapy likely contributed significantly to these improvements through enhanced proprioception, lower limb muscle strength, and balance control.[17,18] The addition of MI possibly augmented the neural drive, facilitating motor planning and execution, thus further enhancing functional outcomes such as gait and balance.[19,20] Greater BI improvements in the MI combined with WBV group were attributed to enhanced functional independence and psychological confidence facilitated by multimodal sensory and cognitive stimuli from MI and WBV. Improvements in neuromuscular efficiency and cognitive-motor integration translated directly into better performance in daily activities, thus increasing patient autonomy and overall quality of life.[21,22]

There are some limitations to this study: firstly, it is a single center retrospective analysis with a small sample size; Secondly, WBV therapy involves a fixed frequency and fixed position. Thirdly, without long-term follow-up, the impact of the combination of MI and WBV therapy on the long-term functional recovery of patients remains to be verified. We will continue to conduct higher-quality research in the future to validate the content of this conclusion.

Conclusion

The combined MI and WBV therapy is superior to conventional training in improving upper limb function, electrophysiological responses, and daily living ability, highlighting its strong potential for clinical rehabilitation practice.

Abbreviations

MI, motor imagery; WBV, whole-body vibration; MMT, manual muscle testing; FM-UL, Fugl-Meyer Upper Limb Scale; ARAT, Action Research Arm Test; BBS, Berg Balance Scale; BI, Barthel Index.

Data Sharing Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Statement

All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee(s) and the Helsinki Declaration (as revised in 2013). The requirement for informed consent was waived by the ethics committee due to the observational and retrospective nature of the study. Throughout the entire research process, these data have been fully de-identified and kept confidential. Our study was approved by the Ethics Review Board of The Sixth People's Hospital of Chongqing.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

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